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REPORT

June 2020

CITY OF
Fitchburg
MASSACHUSETTS

Preliminary Plan of Action for the North Nashua River Flood Damage Reduction System

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

Weston & Sampson, on behalf of the City of Fitchburg, conducted a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System. The objective of the vulnerability assessment was to assess the condition of the FDR System, evaluate potential flooding risks, how those risks may change under future climate scenarios, what the associated impacts of potential flooding may be, and to identify projects that should be completed to improve the functionality and integrity of the FDR System. The flood risk and associated impacts analyses were summarized in technical memoranda in February and April 2020, respectively. This report may serve as a Preliminary Plan of Action for updating and improving the FDR System to reduce flooding impacts to the city.

Weston & Sampson developed a list of 11 improvement projects that the city should consider implementing. The projects range from general maintenance projects, dredging of the channel, minor concrete/masonry repairs, rehabilitation and/or replacement of floodwalls, and expansion/augmentation of existing features to protect from flooding. Projects were evaluated in terms of their priority and potential cost. Of these 11 projects, one was considered to have the highest priority: vegetation maintenance along slopes. The estimated cost for this project is $80,000. Removing vegetation from the slopes is likely to reveal additional projects, modify project prioritization, and may modify estimated project costs. We have identified several projects as having a moderate priority. Of these projects, we feel armoring unprotected slopes, Circle Street Building Rehabilitation, and Minor Floodwall Repairs are most likely to be found to have higher priorities. The Crocker Field Flood Storage project would provide real benefits in an area that has been identified as at risk under baseline and future climate scenarios and would be an important and highly visible project within the community of Fitchburg.

1.0 INTRODUCTION

Weston & Sampson was hired by the City of Fitchburg to conduct a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System in Fitchburg, MA. The FDR System is an approximately five-mile stretch of flood protection along the North Nashua River. The City of Fitchburg has been provided $65,000 through a Municipal Vulnerability Preparedness (MVP) Planning Grant to fund this effort. The goal of the vulnerability assessment is to assess the condition and evaluate potential future flooding risks of the existing FDR System. Refer to ***Appendix A*** for the memorandums produced in support of the vulnerability assessment.

Weston & Sampson completed an analysis of flood levels in the North Nashua River using both USGS gage data as well as the design flows from the effective FEMA Flood Insurance Study (FIS), dated 1991, and an update set of design flows included in a draft update to FEMA's FIS that has not yet been finalized. Using these three datasets, Weston & Sampson estimated 100-year flood levels at 41 different locations within the five-mile reach of river protected by the FDR system. Flood levels were evaluated under both baseline and late 21st century future climate scenarios. Flood level analyses were summarized in a "Flood Risk Memorandum," dated January 31, 2020.

Based on that analysis, Weston & Sampson evaluated the potential impacts to infrastructure, buildings, and lives that are protected by the FDR System. That work included the identification of likely inundation areas during the 100-year flood event, the depth of flooding in those areas, and which buildings might be impacted. Flood depths at critical infrastructure within the City and bridge crossings over the North Nashua River were identified as well. That impact assessment was summarized in a "Flooding Impacts Memorandum," dated April 29, 2020.

Weston & Sampson was also tasked with assessing the condition of the FDR system and identifying projects necessary to ensure its continued usefulness and structural integrity. We conducted two site visits for the purpose of inspecting the FDR System, on August 30, 2019 and again on January 20, 2020. We also reviewed two dozen documents regarding the system and flood hazards in Fitchburg. This assessment was summarized in an "Existing Information Memorandum," dated January 30, 2020. Building from those visual inspections and from our extensive file review, Weston & Sampson has identified a series of projects that would improve the integrity of the FDR system and ensure its continued usefulness. This report, which may serve as a Preliminary Plan of Action for the city, identifies those projects, describes their location and the type of work necessary, a preliminary evaluation of the potential permitting involved, a potential cost estimate, and our assessment of their likely priority.

2.0 BACKGROUND

The North Nashua River FDR System is an approximately five-mile long flood protection system. The FDR System has a drainage area of approximately 64 square miles at the downstream end (just upstream of the confluence of Baker Brook) and a drainage area of approximately 60 square miles at the upstream end (just upstream of the confluence of Phillips Brook). The North Nashua River snakes through the center of Fitchburg where it is abutted by numerous industrial, commercial, and residential structures. The FDR System is generally located between Oak Hill Road and Bemis Road. The purpose of the FDR System to protect the heavily developed City of Fitchburg from riverine flooding. Refer to *Figure 1* for a locus map of the FDR System.

The original flood protection system (then known as the Fitchburg Local Protection Project) was constructed in 1937 in response to a large flood in March 1936. The original project included removing dams, straightening, and widening the channel, and construction retaining walls and revetments. The original design was based on the March 1936 storm flow (approximately 9,000 cfs). Historic flooding events were later observed in the North Nashua River Basin in September 1938, June 1944, and October 1955. Since then, several channel rehabilitation and dam removal projects have been completed. In 1955, the U.S. Army Corps of Engineers (USACE) restored portions of the channel including debris and soil deposit removal and filling bank slopes. Emergency repair work was completed in 1968. The channel was later rehabilitated to its original capacity between 1979 and 1981

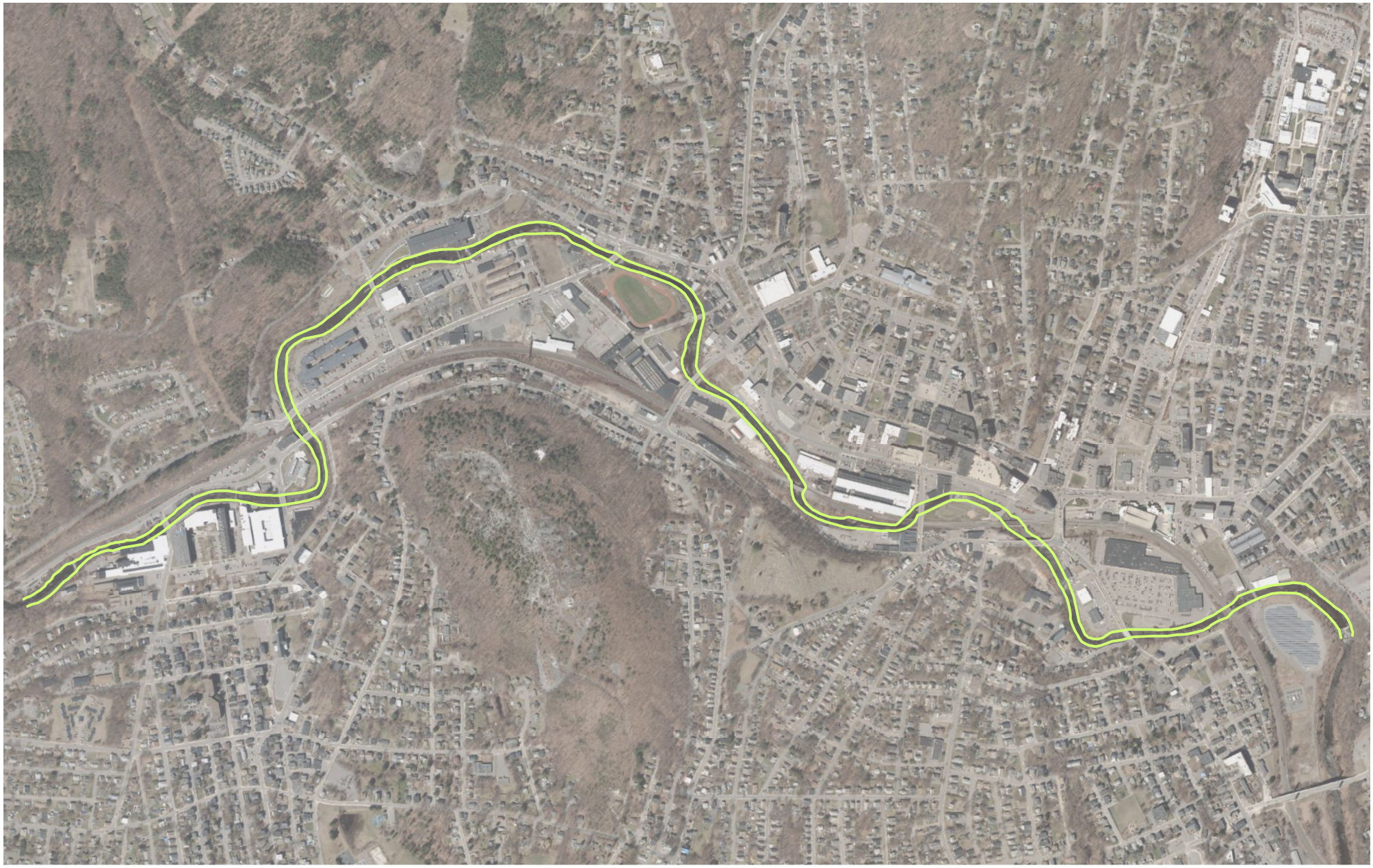

FIGURE 1
CITY OF FITCHBURG
LOCUS MAP

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FDR System Alignment

1,000 0 1,000
Scale In Feet

Weston & Sampson

3.0 CONDITION ASSESSMENT

Weston & Sampson conducted a file review as part of the condition assessment of the North Nashua River FDR System. After reviewing the available documents, we found that the 2019 USACE Inspection Report was useful in evaluating the condition of the North Nashua River FDR System. FEMA's Flood Insurance Study, USACE's North Nashua River Channel Rehabilitation Study, and MRPC's Fitchburg, MA: South Fitchburg Local Hazards Map were helpful in evaluating areas of potential flood risk. Potential flood risk was used to aid in the prioritization of projects described in Section 4.

The 2019 USACE Inspection Report found that the overall system was in unacceptable condition. This rating means that the system may not perform as intended due to the significant deficiencies identified. Generally, the deficiencies noted by the USACE have continued to worsen over the years. The most common remarks made regarded significant vegetation along the banks and in the channel along the entire North Nashua River FDR System. The vegetation ranged from thick brush to large trees. Shoaling was present in many locations as well, which contributed to the overgrowth in the channel, and reduces the North Nashua River's hydraulic capacity. Floodwalls that were visible had signs of deterioration, including cracks, efflorescence, and missing concrete.

Weston & Sampson conducted two site visits to visually observe the FDR System and document our findings, the first on August 31, 2019 and a follow-up visit on January 20, 2020. Observations were made between the Depot Street crossing and the Bemis Road crossing. Overall, our observations were consistent with those identified in the 2019 USACE Inspection Report.

During both site visits, significant vegetation, including brush and trees was, present along the channel slopes for much of the FDR System, which obscured observation of several locations. Slope protection on the earthen sections could not be observed due to the vegetation. Specific observations of the primary deficiencies identified during our initial site visit are discussed below.

Dense vegetation, including brush and trees, were present along the slopes and in the channel for much of the FDR System. The vegetation obscured observation in several locations. Significant vegetation, enabled, in part, by significant shoaling, was present in many locations within the North Nashua River reach protected by the FDR System.

Shoaling, the deposition of eroded bank material within the river channel, was observed in multiple locations. Shoaling can occur in the center of the channel or along the bottom toe of either riverbank. This deposition increases the likelihood of unwanted vegetative growth and decreases the hydraulic capacity of the channel.

Areas with unprotected slopes were also observed, such as the right bank between River Street and Sheldon Street. Observations of unprotected slopes were limited by dense vegetation. Unprotected slopes are susceptible to erosion, which can deposit sediment into the channel.

Trees were present within a retaining wall on the left downstream bank near the River Street Bridge at Crocker Field. The trees appear to have displaced stone blocks within the retaining in this location. Dense vegetation prevented observations of similar occurences elsewhere in the FDR system, but they are likely.

Many of the floodwalls along the FDR System were unobservable due to vegetation. However, of the observable floodwalls, several were observed with significant deterioration including spalling and cracking.

The concrete floodwalls along the left side of the river between Putnam Street and Commercial Street had missing concrete within the approximate top one foot of the walls in at least three locations. Each missing section was approximately 10 feet long. These reduce the flood level against which the FDR System can effectively function in this area.

The 2019 USACE report noted that observable riprap protected areas showed signs of displacement. Riprap protected slopes could not be observed during our site visits due to dense vegetation. The USACE report also noted that the exterior wall of a brick building wall along the left bank on Circle Street appeared to be failing with debris falling into the channel.

4.0 IDENTIFIED PROJECTS

The USACE considers the condition of the North Nashua River FDR System to be unacceptable. Based on a review of previous USACE inspection reports, site visits, and a vulnerability assessment, several improvement projects have been identified to improve the integrity of the FDR system and ensure its continued usefulness. The projects range from general maintenance projects, dredging of the channel, minor concrete/masonry repairs, rehabilitation and/or replacement of floodwalls, and expansion/augmentation of existing features to protect from flooding. The following table briefly summarizes individual projects.

Table 1: Identified Projects

Project ID #	Project Name	Description	Priority	Relative Cost	Construction Cost Estimate (Permitting Cost Estimate)	Permits Likely Required
1	Vegetation maintenance along slopes	Removal of large brush and trees along channel slopes	***	*	$80k ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF
2	Vegetation maintenance along floodwalls	Removal of trees and brush within 15 feet of floodwalls	**	**	$150k ($8k-$13k)	NOI
3	Supplement riprap	Supplement riprap on slopes where riprap has been displaced	**	**	$350k ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF
4	Armor unprotected slopes	Armor unprotected earthen slopes with riprap	**	**	$250k ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF
5	Circle Street building rehabilitation	The exterior wall of a brick building at Circle Street appears to be bowed outward toward the channel and should be repaired	**	**	$400k ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF
6	Channel dredging	Dredge the channel where shoaling is present	**	***	$1M ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF

7	Minor floodwall repairs	Repair floodwalls that have spalling concrete, efflorescence, and surficial cracking	**	***	$750k ($35k-$45k)	NOI, MEPA ENF, MassDEP WQC, Chapter 91, USACE PNF
8	Riverfront Park floodwall rehabilitation	Rehabilitate floodwalls to fix gaps observed in the top sections of the wall	*	*	$80k ($8k-$13k)	NOI
9	Crocker Riverside Mills floodproofing	Floodproof windows and doors at Crocker Riverside Mills to El. 499	**	*	$100k ($8k-$13k)	NOI
10	Anwelt Heritage Apartments floodproofing	Floodproof utility shed and vents at Anwelt Heritage Apartments	**	*	$100k ($8k-$13k)	NOI
11	Crocker Field flood storage	Replace iron fence around Crocker Field with concrete/stone walls to El. 464 (approx. 2.5 feet tall) and provide four 3-ft. tall bladder dams to use at gates	**	**	$400k ($8k-$13k)	NOI

The 11 improvement projects identified in the summary table above are described in detail on the following pages. Each project description includes at least one photo of an example of the deficiency of concern and a map showing the approximate locations of the improvement project along the FDR System. It should be noted that the costs and permit requirements are general estimates and will need to be re-estimated when new information relevant to each project becomes available. Effective management of vegetation along the riverbank slopes, in particular, will allow the City to more accurately assess the priority or extents of some of the proposed projects and, therefore, more accurately estimate their associated costs.

4.1 Vegetation Maintenance Along Slopes

Significant vegetation consisting of large, dense brush and trees is present along the channel slopes for the entire FDR System. The heavy vegetation prevents a thorough inspection of the FDR System and may obscure additional deficiencies. Root systems from dense vegetation can also damage structures by causing movement and cracking and displace slope protection like riprap. Vegetation within the channel will also reduce the hydraulic capacity of the channel. Vegetation should be removed and maintained. After removal, the FDR System should be re-inspected for additional deficiencies. Once vegetation has been removed, additional deficiencies may be noted, which may result in additional projects, alter cost estimates of existing projects, or alter the prioritization of projects in this report.

We estimated that approximately 12,290 linear feet of slope should be cleared of woody vegetation, which was estimated to cost approximately $80,000. Refer to ***Figure 2*** for the approximate areas of vegetation maintenance. We assume that there will be vegetation removal within the river channel as part of this project. Work within the channel will likely require the following environmental permits: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

4.2 Vegetation Maintenance Along Floodwalls

Tree roots that are adjacent to a floodwall can cause it to become displaced and move towards the channel, reducing the hydraulic capacity of the channel and eventually causing a wall failure. Trees should be removed from within 15 feet of floodwalls to reduce the chances of a wall failure. Refer to *Figure 2* for the approximate areas of vegetation maintenance.

A specific location where trees have caused displacement in the FDR System already is at the River Street Bridge near Crocker Field. Trees have displaced the stone blocks of the retaining wall at the left bank. The trees should be removed from within 15 feet of the wall and the wall should be repaired, as necessary.

Based on site visits, photographs, and aerial imagery, we estimate that approximately 170,950 square feet of area around the floodwalls will need to be cleared. This work could cost approximately $150,000. For permitting, we assume that no work will be done within the channel. A Notice of Intent will likely be required. The costs associated with preparing and submitting this permit would be in the $8,000 - $13,000 range.

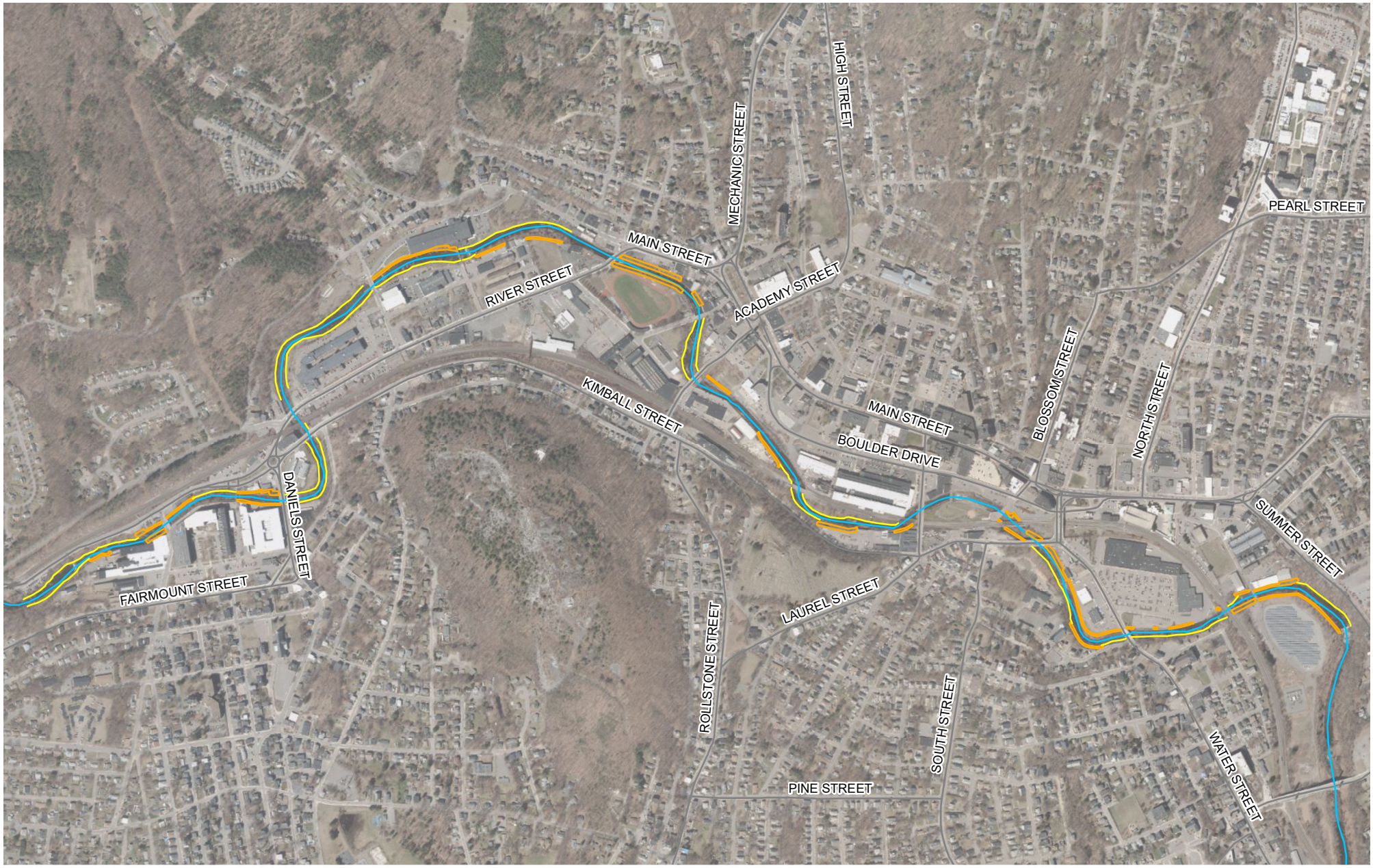

FIGURE 2
CITY OF FITCHBURG
VEGETATION MAINTENANCE

- Vegetation On Slope
- Vegetation Along Floodwalls
- River Centerline
- MassDOT Major Roads

N

1,000 0 1,000
Scale In Feet

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4.3 Supplement Riprap

The USACE noted that, in several locations, riprap has been displaced and should be restored. Riprap protects earthen slopes from erosion. It can also limit the presence of vegetation. Displaced riprap leaves the slope exposed. *Figure 3* shows the locations of areas where riprap is present but will likely need to be supplemented. It should be noted that once the vegetation has been removed from the slopes, the estimated quantity needed may change.

There is approximately 12,290 feet of earthen slope along the FDR System. We estimate that approximately 7,850 feet of that length has existing riprap slope protection. We are assuming that all existing riprap sections will need to be supplemented with additional riprap. Based on these assumptions, the estimated cost is approximately $350,000. The riprap will likely be placed below the normal waterline. The following environmental permits may be required: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

4.4 Armor Unprotected Slopes

Armoring of slopes with riprap reduces the effects of erosion on slope stability. Riprap can also reduce vegetation growth on slopes. Much of the earthen slopes were overgrown with vegetation, obscuring observation of the presence of riprap.

Based on different aerial images, the USACE inspection reports, and our site visits, we have estimated that approximately 4,400 feet of the FDR System does not have a significant amount, if any, armoring. *Figure 3* shows the locations of areas where little to no riprap is currently present. It should be noted that once the vegetation has been removed from the slopes, the prioritization of this project may change depending on the condition of the slopes. In addition, the estimated quantity needed may change. This work is estimated to cost approximately $250,000. The riprap will likely be placed below the normal waterline. The following environmental permits may be required: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

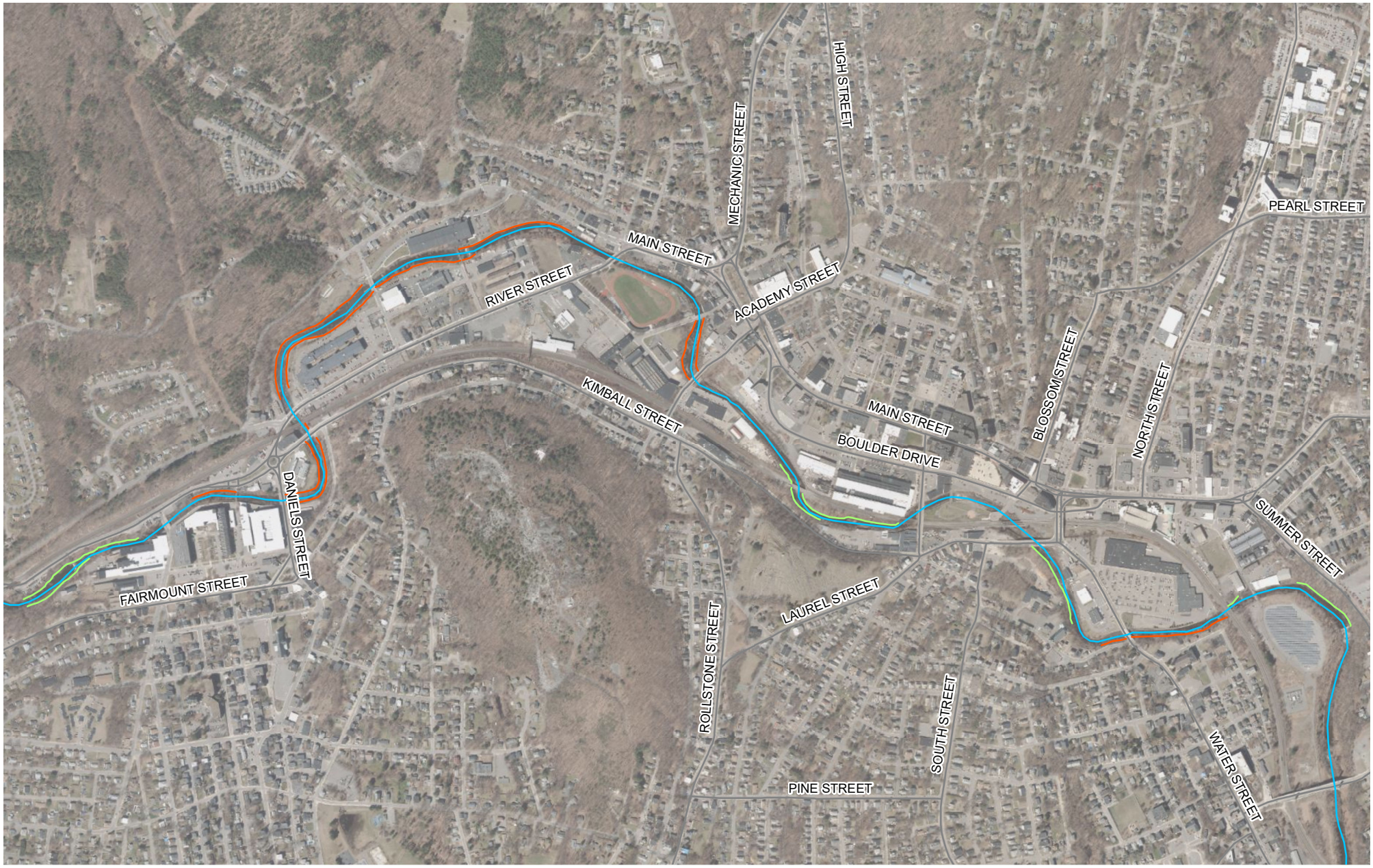

FIGURE 3
CITY OF FITCHBURG
SLOPE PROTECTION

- New Riprap
- Supplemented Riprap
- River Centerline
- MassDOT Major Roads

N

1,000 0 1,000
Scale In Feet

Weston & Sampson

4.5 Circle Street Building Rehabilitation

Several USACE inspection reports note that the exterior wall of a brick building wall along the left bank on Circle Street appeared to be bowing and failing, with debris falling into the channel. The exterior wall adjacent to the river is approximately 40 feet long. The elevation of water at the building during the 100-year flood is approximately El. 459 ft. NAVD88, which is approximately 10 feet above the channel bottom. Refer to ***Figure 4*** for the location of the building. The city should work with owner of the building to repair the wall. based on visual observations, it appears that the building is not in active use, which has led us to categorize this project as having a moderate priority. If the building use changes, the priority of the project should be revisited.

Based on the limited information available on this structure, we assume that the wall will be shored up from the exterior using wide flange steel beams and diagonal kicker braces. A horizontal support will be required at each level including the roof. This work could cost approximately $400,000. If there isn't enough room to drop the exterior kicker braces, the existing wall may need to be reconstructed or reinforced, which would be a substantially more expensive option. Assuming that there will be temporary dewatering of the channel for this work and likely work in the channel for building stabilization, the following environmental permits will likely be required: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

FIGURE 4
CITY OF FITCHBURG
CIRCLE STREET BUILDING REHABILITATION

- Circle Street Building Rehabilitation
- River Centerline
- MassDOT Major Roads

N

100 0 100

Scale In Feet

Weston & Sampson

4.6 Channel Dredging

The USACE inspection reports note significant shoaling along much of the FDR System. Shoaling reduces the hydraulic capacity of the system and provides additional surfaces on which vegetation is likely to grow. We estimate that approximately 277,000 cubic feet of material may need to be dredged. This estimate is based off an estimation of the surface area of likely shoals, as shown in ***Figure 5***, or approximately 138,500 square feet, and a depositional depth of two feet. It should be noted that the depth of shoaling may range between approximately six inches and more than three feet.

Sediment removal within the channel will likely trigger the following environmental permits: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

FIGURE 5
CITY OF FITCHBURG
CHANNEL DREDGING

Dredging
River Centerline
MassDOT Major Roads

N

1,000 0 1,000
Scale In Feet

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4.7 Minor Floodwall Repairs

The floodwalls are generally made of concrete or stone masonry. The visible portions of the walls have noticeable deficiencies such as spalling, cracking and efflorescence. Much of the floodwalls could not be observed due to vegetation. Based on the condition of the visible portions of floodwalls, we assume that all flood walls will need minor repairs. This estimate may change after the floodwalls are exposed by vegetation removal. In addition, more significant floodwall repairs may be exposed, which may increase the prioritization of this project.

For estimating purposes, we assume that the average floodwall height is 10 feet and that there are approximately 14,780 feet of floodwalls along the FDR System. The estimated length of floodwalls is shown in ***Figure 6.*** We also assume that 2% of the wall surfaces need repairing. The estimated repair cost is approximately $750,000. Assuming that there will may be temporary dewatering of the channel for this work, the following environmental permits will likely be required: a Notice of Intent, a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF), a Massachusetts Department of Environmental Protection (MassDEP) Water Quality Certificate (WQC), a MassDEP Chapter 91, and a United States Army Corps of Engineers (Corps) Pre-Construction Notification (PNF). Costs associated with preparing and submitting these permits would be in the $35,000 - $45,000 range.

FIGURE 6
CITY OF FITCHBURG
MINOR FLOODWALL REPAIRS

Floodwalls
River Centerline
MassDOT Major Roads

N

1,000 0 1,000
Scale In Feet

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4.8 Riverfront Park Floodwall Rehabilitation

The USACE inspection report notes gaps in the floodwall between Putnam Street and Commercial Street near Riverfront Park. Based on visual observations, there appear to be four 10-foot wide areas where the approximate top foot of the floodwall has been removed. These sections should be repaired to match the top of the adjacent wall sections. ***Figure 7*** identifies the four locations.

Each of the four sections is estimated to cost approximately $20,000 to repair. We are assuming that this work can be done without impacting the channel. Therefore, a Notice of Intent will be required. It will cost between approximately $8,000 and $13,000 to prepare and submit this permit.

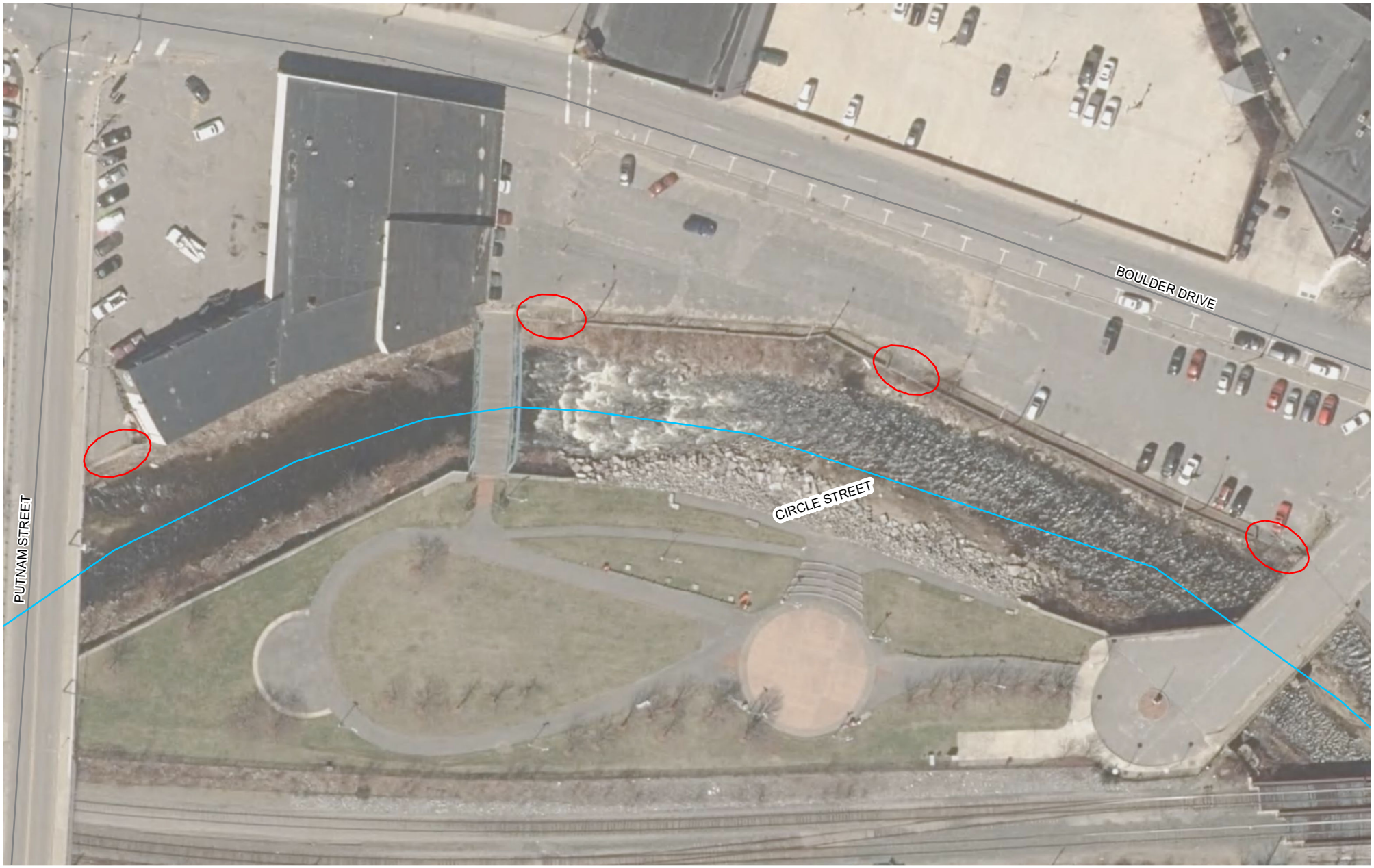

FIGURE 7
CITY OF FITCHBURG
RIVERFRONT PARK FLOODWALL REHABILITATION

Riverfront Park Floodwall Gap Locations
River Centerline
MassDOT Major Roads

100 0 100
Scale In Feet

N

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4.9 Crocker Riverside Mills Floodproofing

The Crocker Riverside Mills abuts the North Nashua River. Based on our flood risk and impact analyses, the reach of the FDR System upstream of Oak Hill Road may be vulnerable to overtopping with flood levels reaching up to El. 499. The windows on the river side of the first floor of the building should be floodproofed to prevent the interior of the building from flooding. We estimate that there are approximately 60 windows. Refer to ***Figure 8*** for the project location.

One way to floodproof windows is to brick them. Brick costs approximately $50 per square foot. We estimate that each window is approximately 30 square feet based on field observations. The total cost for this project is, therefore, approximately $100,000. Measurements should be taken in the field for a more accurate estimate. Assuming that work will occur within 200 feet from the channel or in the 100-foot flood zone, a Notice of Intent will likely be required. Costs associated with preparing and submitting this permit would be in the $8,000 - $13,000 range.

FIGURE 8
CITY OF FITCHBURG
CROCKER RIVERSIDE MILLS FLOODPROOFING

- Crocker Riverside Mills
- River Centerline
- MassDOT Major Roads

N

100 0 100

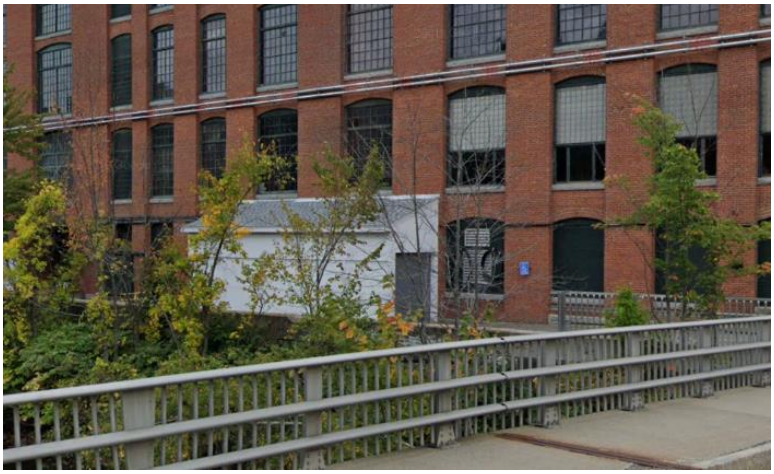
Scale In Feet

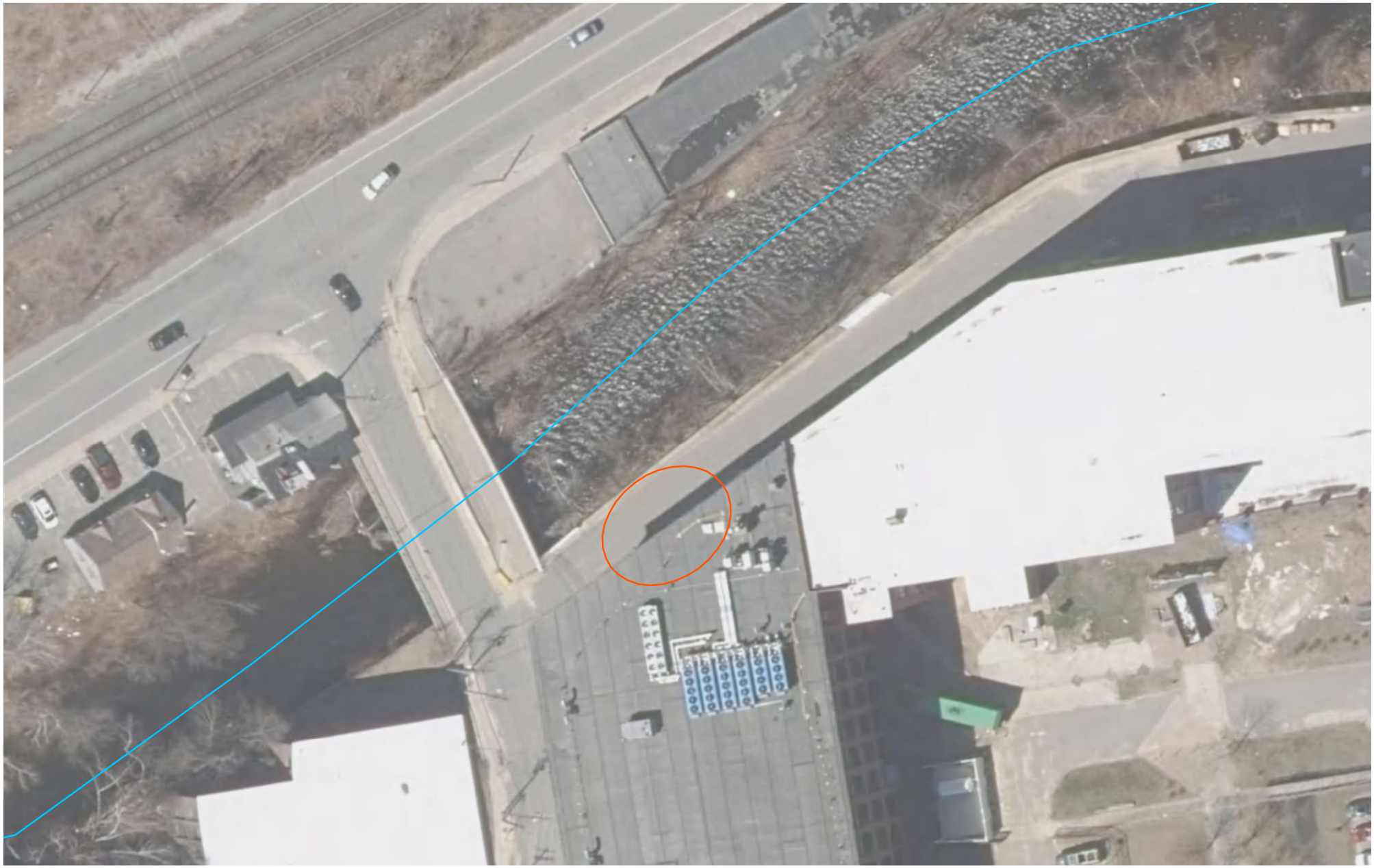
Weston & Sampson

4.10 Anwelt Heritage Apartments Floodproofing

Based on our flood risk and impact analyses, the reach of the FDR System between Oak Hill Road and Daniels Street may be vulnerable to overtopping with flood levels reaching up to El. 498 ft. NAVD88. The Anwelt Heritage Apartments building is located in this area and is shown in ***Figure 9***. A shed is present on the river side of the Anwelt Heritage Apartments building. This shed may contain utilities. In addition, there is a vent in the mill building's exterior wall adjacent to this shed. Both may be impacted by a flood. These and any other critical infrastructure associated with the building should be floodproofed. Since the old mill building has been refurbished, we assume that the first floor doors and windows have already been waterproofed.

There are many unknowns about the purpose of the shed and vent, making it difficult to cost out floodproofing. The city should work with the building owner to assess the best way to floodproof. We are using a $100,000 estimate as a placeholder for this project. Assuming that work will occur within 200 feet from the channel or in the 100-foot flood zone, a Notice of Intent will likely be required. Costs associated with preparing and submitting this permit would be in the $8,000 - $13,000 range.





Anwelt Heritage Apartments Utility Shed and Vent Location

River Centerline

MassDOT Major Roads

FIGURE 9
CITY OF FITCHBURG
ANWELT HERITAGE APARTMENTS FLOODPROOFING

N

100 0 100

Scale In Feet

4.11 Crocker Field Flood Storage

Based on our flood risk and impact analyses, the reach of the FDR System near Crocker Field may be vulnerable to overtopping with flood levels reaching up to El. 464. During a flood, Crocker Field will act as a conduit for overflows to reach adjacent low-lying areas. To reduce the impacts of flooding on this area, Crocker Field can be used as intentional flood storage during a storm event. Currently, an approximately 1,125-foot-long iron fence with four 8-foot wide gates surrounds Crocker Field on the three non-river sides. The outline of the existing fence is shown in *Figure 10*. The fence can be replaced with an approximately 2.5-foot tall concrete or stone masonry wall that will act as a barrier between the surrounding streets and Crocker Field. Four 3-foot-tall bladder dams can be built into the ground at the gate locations to prevent flow from passing through These bladder dams would be embedded in the concrete ground surface normally but could be quickly inflated during large flood events.

The concrete work associated with the new wall is estimated to cost approximately $250,000-$350,000. Assuming that the top section of the wall will be iron fence again, we assume between $50 and $100 per linear foot of fencing. A total construction was estimated at approximately $400,000. Assuming that work will occur within 200 feet from the channel or in the 100-foot flood zone, a Notice of Intent will likely be required. Costs associated with preparing and submitting this permit would be in the $8,000 - $13,000 range.

FIGURE 10
CITY OF FITCHBURG
CROCKER FIELD FLOOD STORAGE

- Crocker Field Fence
- River Centerline
- MassDOT Major Roads

100 0 100
Scale In Feet

N

Weston & Sampson

5.0 CONCLUSION

Weston & Sampson has completed a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System in Fitchburg, MA. The vulnerability assessment consisted of a condition assessment, flood risk analysis, and an impacts analysis. Based on that work, Weston & Sampson developed a list of 11 improvement projects for the city to consider that would improve the integrity and usefulness of the FDR System, enhancing its effectiveness under baseline and future climate scenarios. The projects range from general maintenance projects like vegetation removal to channel dredging to significant structural improvements. The project that we consider to be the highest priority is vegetation maintenance along slopes. The estimated cost for this project is $80,000. More field data and analyses are necessary for more accurate cost estimates for these projects. Removing vegetation from the slopes is likely to reveal additional projects, modify project prioritization provided in Section 4, and may modify estimated project costs. We have identified several projects as having a moderate priority. Of these projects, we feel armoring unprotected slopes, Circle Street Building Rehabilitation, and Minor Floodwall Repairs are most likely to be found to have higher priorities. The Crocker Field Flood Storage project would provide real benefits in an area that has been identified as at risk under baseline and future climate scenarios and would be an important and highly visible project within the community of Fitchburg.

6.0 REFERENCES

1. Community Resources for Fitchburg Residents, Office of Community Development, City of Fitchburg
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3. Operation and Maintenance Manual for Local Protection Project, USACE
4. Flood Damage Reduction Segment / System Inspection Report, USACE, June 28, 2019
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6. Flood Damage Reduction Segment / System Inspection Report, USACE, June 14, 2018
7. Economic Trends Fitchburg, Massachusetts, Edward J. Collins Jr. Center for Public Management at the University of Massachusetts, Boston, February 2018
8. Montachusett Region Natural Hazard Mitigation Plan 2015 Update, Montachusett Regional Planning Commission (MRPC), 2015
9. Fitchburg, MA: South Fitchburg Local Hazards Map, MRPC, 2015
10. Flood Damage Reduction Segment / System Inspection Report, USACE, September 25, 2014
11. Open Space and Recreation Plan Update, City of Fitchburg, 2014
12. Environmental Justice Populations, Massachusetts Executive Office of Environmental Affairs, 2010
13. North Nashua River Restoration Q&A, USACE, November 25, 2009
14. North Nashua River Restoration Notice, USACE, June 6, 2006
15. Flood Damage Reduction Segment / System Inspection Report, USACE, May 30, 2006
16. Fitchburg Local Protection Project and West Habitat Restoration Alternatives Analysis Report, USACE, December 2004
17. Flood Damage Reduction Segment / System Inspection Report, USACE, October 22, 2003
18. North Nashua River Channel Rehabilitation Study, USACE, June 2003
19. Flood Damage Reduction Segment / System Inspection Report, USACE, May 28, 2003
20. Flood Damage Reduction Segment / System Inspection Report, USACE, October 25, 2002
21. Flood Damage Reduction Segment / System Inspection Report, USACE, May 29, 2002

22. Hydrologic Assessment: Nashua River Watershed, CDM, March 2002

23. Compendium for Fitchburg Local Protection Project, USACE, 1977

APPENDIX A

Vulnerability Assessment Memorandums

55 Walkers Brook Drive, Suite 100, Reading, MA 01867
Tel: 978.532.1900

MEMORANDUM

TO:	Nick Erickson, PE (City of Fitchburg)
FROM:	Andrew Walker, PH & Deanna Lambert, EIT (Weston & Sampson Engineers, Inc.)
DATE:	January 30, 2020
SUBJECT:	Existing Information Memorandum

Weston & Sampson was hired by the City of Fitchburg to conduct a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System in Fitchburg, MA. The FDR System is an approximately five mile stretch of flood protection along the North Nashua River. Its approximate location is highlighted by the attached map, taken from the 2018 US Army Corps of Engineers' (USACE) inspection report.

The City of Fitchburg has been provided $65,000 through a Municipal Vulnerability Preparedness (MVP) Planning Grant to fund this effort. The goal of the preliminary vulnerability assessment is to assess the condition and evaluate potential future flooding risks of the existing FDR System. The purpose of this memo is to summarize available information on the FDR based on a file review, anecdotal information, and an in-person condition assessment of the system conducted during site visits on 8/30/2019 and 1/20/2020.

File Review

Weston & Sampson conducted a file review as part of the vulnerability assessment of the North Nashua River FDR System. The following documents were reviewed:

- Community Resources for Fitchburg Residents, Office of Community Development, City of Fitchburg
- Open Space and Recreation Plan Update, City of Fitchburg, 2014
- Draft Wachusett Corridor Smart Growth Plan Open Space and Recreation Element
- 2010 Environmental Justice Populations, Massachusetts Executive Office of Environmental Affairs, 2010
- Economic Development Strategic Plan, City of Fitchburg, October 2018
- Economic Trends Fitchburg, Massachusetts, Edward J. Collins Jr. Center for Public Management at the University of Massachusetts, Boston, February 2018

- Hydrologic Assessment: Nashua River Watershed, CDM, March 2002
- Flood Insurance Study, Federal Emergency Management Agency (FEMA), September 18, 1991
- North Nashua River Channel Rehabilitation Study, USACE, June 2003
- Fitchburg Local Protection Project and West Habitat Restoration Alternatives Analysis Report, USACE, December 2004
- Fitchburg Local Protection Project Preliminary Ranking of Potential Habitat Restoration Alternatives, USACE
- North Nashua River Restoration Notice, USACE, June 6, 2006
- North Nashua River Restoration Q&A, USACE, November 25, 2009
- Operation and Maintenance Manual for Local Protection Project, USACE
- Montachusett Region Natural Hazard Mitigation Plan 2015 Update, Montachusett Regional Planning Commission (MRPC), 2015
- Fitchburg, MA: South Fitchburg Local Hazards Map, MRPC, 2015
- Flood Damage Reduction Segment / System Inspection Report, USACE, May 29, 2002
- Flood Damage Reduction Segment / System Inspection Report, USACE, October 25, 2002
- Flood Damage Reduction Segment / System Inspection Report, USACE, May 28, 2003
- Flood Damage Reduction Segment / System Inspection Report, USACE, October 22, 2003
- Flood Damage Reduction Segment / System Inspection Report, USACE, May 30, 2006
- Flood Damage Reduction Segment / System Inspection Report, USACE, September 25, 2014
- Flood Damage Reduction Segment / System Inspection Report, USACE, June 14, 2018
- Flood Damage Reduction Segment / System Inspection Report, USACE, June 28, 2019

After reviewing the aforementioned documents, we found that the 2018 and 2019 USACE Inspection Reports were useful in evaluating the condition of the North Nashua River FDR System. FEMA's Flood Insurance Study, USACE's North Nashua River Channel Rehabilitation Study, and MRPC's Fitchburg, MA: South Fitchburg Local Hazards Map were helpful in evaluating areas of potential flood risk.

The USACE inspected the North Nashua River FDR System between Oak Hill Road and Bemis Road. The 2018 Inspection Report included a site map that identified the areas that were observed along the North Nashua River FDR System. The 2019 Inspection Report found that the overall system was in unacceptable condition. The most common remarks made regarded significant vegetation along the banks and in the channel along the entire North Nashua River FDR System. Shoaling was present in many locations as well, which contributed to the overgrowth in the channel, and reduces the North Nashua River's hydraulic capacity. Floodwalls that were visible had signs of deterioration, including cracks, efflorescence, and missing concrete.

The FEMA Flood Insurance Study provides a summary of peak discharges in the North Nashua River for the 10-year, 50-year, 100-year, and 500-year floods and provides flood profiles for these floods between the confluence of Whitman River and Flagg Brook and Falulah Road (now Airport Road).

The North Nashua River Channel Rehabilitation Study briefly describes a hydraulic study conducted by the USACE and includes water surface profiles for the North Nashua River between Oak Hill Road and

the Fitchburg Gas and Electric Dam at a design flow of 9,000 cubic feet per second. The river profiles also include an approximate channel bottom and low bank elevation at 41 cross sections locations.

The Fitchburg, MA: South Fitchburg Local Hazards Map contains anecdotal flooding information at several locations along the North Nashua River FDR System. This information was collected from a Community Hazard & Vulnerability Session as part of a 2015 update to the Montachusett Region Natural Hazard Mitigation Plan. Concerns, including shoaling and vegetation along the North Nashua River FDR System, previously observed high water levels and ice jam vulnerability at the Cushing Street crossing and at Boulder Drive beneath Water Street, and basement flooding along Main Street, were all discussed.

Site Visits

Weston & Sampson conducted an initial site visit on August 30, 2019. The purpose of this visit was to visually observe the North Nashua River FDR System and document our findings. Observations were made between the Depot Street crossing and the Bemis Road crossing. Photographs from our site visit are attached at the end of this memorandum. Overall, our observations were consistent with observations made in the 2019 USACE Inspection Report. Based on visual observations, areas of the North Nashua River FDR System that may be flood prone were documented. During a second site visit on 1/20/2020, visual observations of relative bank heights were noted to guide analyses of potential flood risk that will be completed later in this project.

During both site visits, significant vegetation, including brush and trees was present along the channel slopes for the entire North Nashua River FDR System, which obscured observation of several locations. The significant vegetation made it difficult to evaluate where one structure ended, and another began. Slope protection on the earthen sections could not be observed due to the vegetation. However, specific observations made during our initial site visit include:

- Dense vegetation, enabled, in part, by significant shoaling in many locations along the FDR system (see photos 1 through 6);
- The right bank between River Street and Sheldon Street was unprotected (see photo 2);
- The presence of trees and displaced stone blocks within a retaining wall on the left downstream bank of the River Street bridge (see photo 7);
- Several floodwalls with significant deterioration and cracking (see photos 8 and 9); and
- Floodwalls near Putnam Street and Commercial Street had missing concrete within the approximate top one foot of the walls.
- The USACE report noted that observable riprap protected areas showed signs of displacement.
- The USACE report noted that the exterior wall of a brick building wall along the left bank on Circle Street appeared to be failing with debris falling into the channel.

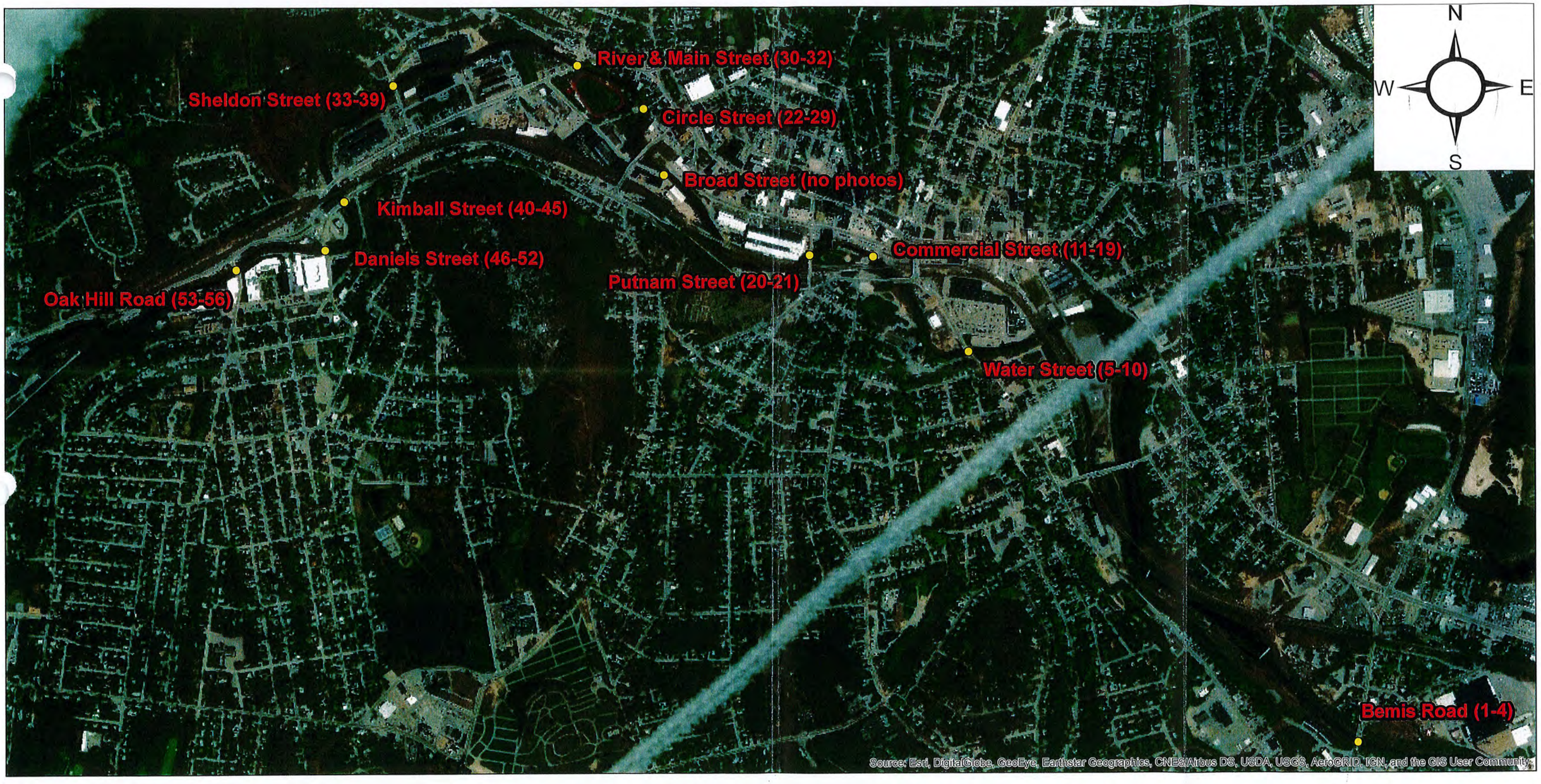
Next Steps

Following the review of existing information documented in this memo, Weston & Sampson has begun analyses of the flood risk that the North Nashua River poses to the City of Fitchburg and which sections of the FDR System may be most vulnerable under baseline and future climate conditions. The next steps in those analyses include:

- Prepare a profile view of the FDR system, identifying the lowest bank elevation and the 100-year flood elevation under baseline and future climate conditions;
- Identify which areas of the FDR system are vulnerable now, and which will become vulnerable in the future;
- Translate the elevation information from a profile view to GIS;
- Conduct preliminary breach analyses in GIS to identify which areas of the city are most vulnerable to flooding from the North Nashua River or a failure of the FDR system under baseline and future climate conditions;
- Develop an action plan with projects identified and prioritized along with engineering cost estimates to repair/replace critical components.

Attachments:

Site Map (from the 2018 USACE Inspection Report)
Partial Photo Log from 8/30/2019 Site Visit



0 900 1,800 3,600 5,400 7,200 Feet

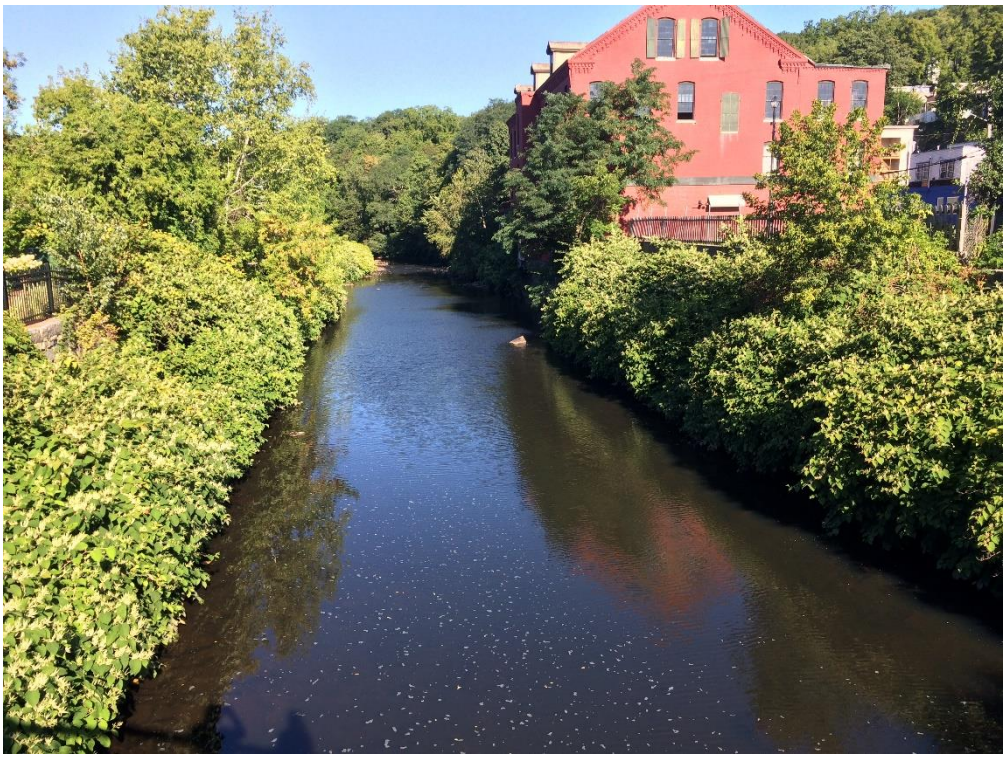
North Nashua River
Flood Damage Reduction System
Fitchburg, MA
Routine Inspection
June 14, 2018

Partial Photo Log from 8/30/2019 Site Visit

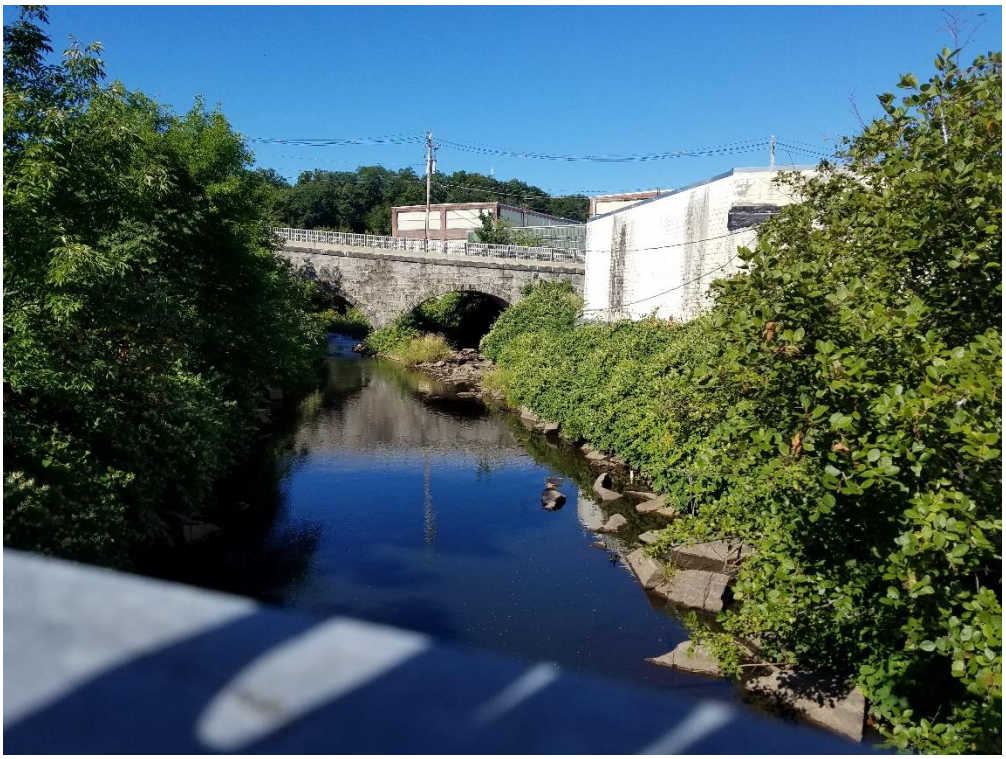
Photograph 1: Vegetation and shoaling downstream of Oak Hill Road.

Photograph 2: Vegetation and unprotected slope downstream of River Street and upstream of Sheldon Street.

Photograph 3: Vegetation downstream of Putnam Street and upstream of Commercial Street.



Photograph 4: Vegetation upstream of River Street.



Photograph 5: Vegetation and shoaling downstream of Putnam Street.

Photograph 6: Vegetation and shoaling downstream of Commercial Street.

Photograph 7: Vegetation and displaced stone blocks downstream of River Street.

Photograph 8: Vegetation and floodwall upstream of Oak Hill Road.

Photograph 9: Cracks and deterioration of the floodwall downstream of Commercial Street.

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MEMORANDUM

TO:	Nick Erickson, PE (City of Fitchburg)
FROM:	Andrew Walker, PH & Deanna Lambert, EIT (Weston & Sampson Engineers, Inc.)
DATE:	April 30, 2020
SUBJECT:	Flood Risk Memorandum

Weston & Sampson was hired by the City of Fitchburg to conduct a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System in Fitchburg, MA. The FDR System is an approximately five mile stretch of flood protection along the North Nashua River. The City of Fitchburg has been provided $65,000 through a Municipal Vulnerability Preparedness (MVP) Planning Grant to fund this effort. The goal of the preliminary vulnerability assessment is to assess the condition and evaluate potential future flooding risks of the existing FDR System. This memo documents Weston & Sampson's efforts to identify the 100-year flood flow in the North Nashua River under baseline and future climate conditions, and then to evaluate which portions of FDR System are most vulnerable to overtopping and/or failure. Future analyses in support of this project will determine which portions of Fitchburg are therefore at greatest risk to flood hazards.

The 100-year design flow under baseline climate conditions was evaluated from three separate datasets, including 1) streamflow data recorded at the United States Geological Survey (USGS) gage on the North Nashua River (01094400), 2) the effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) dated 1991, and 3) the new Draft FEMA FIS. Estimates of the 100-year flood were first developed through statistical analysis of annual peak streamflow data observed between 1973 and 2018 at the North Nashua USGS gage. This USGS 100-year flood value was 71.89 cubic feet per square mile (cfsm). The 1991 FEMA Flood Insurance Study provided a FEMA 100-year flow value that was considerably different from this value. The FEMA 100-year flow was provided for the North Nashua River at four locations, including the confluence with Bakers Brook, which is immediately downstream of the project area. FEMA's design flow for that location was 15,000 cfs; however, the drainage area associated with that location in the report appears erroneous based on more recent topographic data. When that 100-year flow rate is weighed against a drainage area estimated using the StreamStats tool, the FEMA 100-year design flow is estimated at approximately 177.5 cfsm. Recently, FEMA has drafted a new FIS and conducted workshops with the associated Nashua River communities. The 100-year flows and flood elevations from the new draft FIS are considerably lower than the effective FEMA FIS. The new Draft FEMA design flow was 103.9 cfsm.

Estimates of the 100-year design flood under future climate conditions were determined based on projected increases in design rainfall depths. Based on the November 2015 Climate Change Vulnerability Assessment conducted for the City of Cambridge, the 100-year, 24-hour design rainfall depth is expected to increase by 31.4% by the late 21st century. We assumed that streamflow would increase accordingly. Therefore, the future USGS, 1991 FEMA FIS, and new Draft FEMA FIS 100-year design flows were 94.46 cfsm, 233.2 cfsm, and 136.5 cfsm, respectively.

The United States Army Corp of Engineers (USACE) concluded a Rehabilitation Study of the North Nashua River Channel in June 2003. This report included a profile view representation of USACE's hydraulic model of the North Nashua River within Fitchburg. These profiles formed the basis for our analysis of the most vulnerable sections of the FDR System to overtopping/breaching. The profiles identified the approximate low bank elevation at 41 different locations within the project area. We developed rating curves for the 10-, 50-, 100-, and 500-year flood events at each of these 41 locations, based on the design flows and corresponding peak water surface elevations identified in the 1991 FEMA FIS. The rating curves were used to translate the three baseline flows and three future climate flows into estimates of river stage. The USACE profiles with our six design floods are attached at the end of this memorandum. Table 1 summarizes our estimate of river stage at each of the 41 low bank locations, and Table 2 indicates the potential depth of overtopping flow at those locations.

As presented in Table 2 and the attached river profiles at the end of this memo, none of the 41 low bank locations are expected to overtop during the USGS 100-year baseline or future climate flood event. None of the 41 low bank locations are expected to overtop during the Draft FEMA 100-year baseline flood either, although one, upstream of Oak Hill Road, is expected to overtop during the corresponding future climate scenario. However, many (8) segments of the North Nashua River FDR System are shown to overtop under the effective (1991) FEMA 100-year baseline flood, and many more (24 total) are expected to be overtopped under the corresponding future climate scenario.

Next Steps

Following the review of existing information documented in this memo, Weston & Sampson has begun analyses of the flood risk that the North Nashua River poses to the City of Fitchburg and which sections of the FDR System may be most vulnerable under baseline and future climate conditions. The next steps in those analyses include:

- Translate the elevation information from a profile view paper view to a Geographic Information System (GIS);
- Analyze, in GIS, which areas of the city are most vulnerable to flooding from the North Nashua River or by a failure of the FDR system under baseline and future climate conditions; and
- Develop an action plan with projects identified and prioritized along with engineering cost estimates to repair/replace critical components.

Attachments:

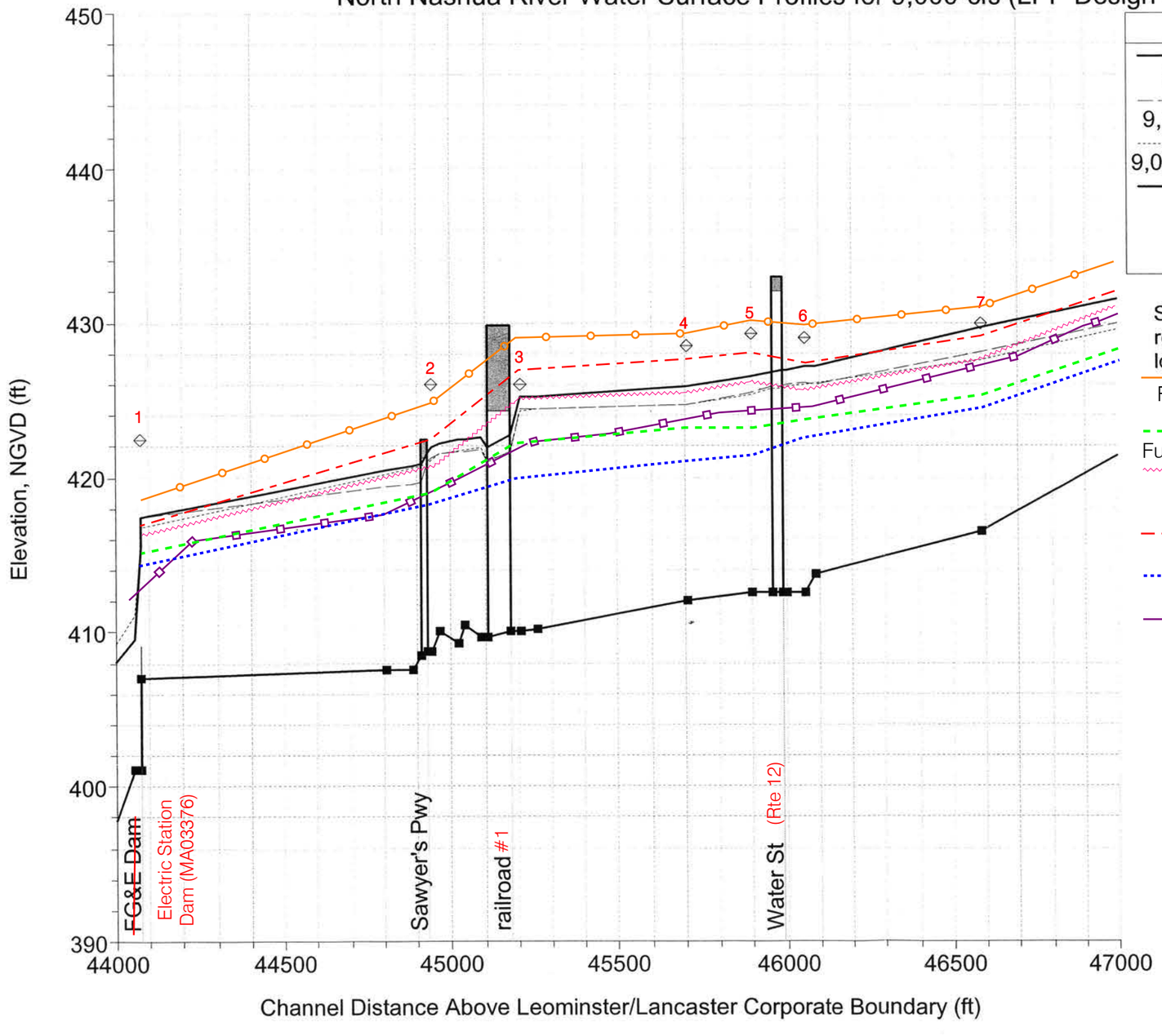
River Profiles (from the 2003 USACE Rehabilitation Study)

Low Bank ID	Approximate Location	Low Bank Elev.	Estimated 100-yr River Stage Elevation (ft. NAVD88)					
			USGS Baseline	USGS Future	Effective (1991) FEMA Baseline	Effective (1991) FEMA Future	Draft FEMA Baseline	Draft FEMA Future
1	Upstream of Electric Station Dam	422.5	414.7	415.2	417.4	418.9	413.0	416.3
2	Upstream of Sawyers Pwy	426.0	418.4	419.3	422.5	424.7	419.0	420.9
3	Upstream of railroad #1	426.0	420.0	422.2	427.1	429.2	422.0	425.0
4	Downstream of Water St	428.5	421.0	423.0	427.7	429.7	424.5	425.4
5	Downstream of Water St	429.5	421.4	423.5	428.2	430.2	424.2	426.2
6	Upstream of Water St	429.0	422.5	423.5	427.3	429.8	423.7	425.8
7	Downstream of Laurel St	430.0	424.6	425.5	428.9	431.2	427.0	427.2
8	Upstream of Laurel St	434.5	429.9	430.8	434.4	436.8	438.7	440.2
9	Upstream of railroad #2	434.5	431.0	432.0	435.4	437.7	435.0	434.6
10	Upstream of Commercial St	443.0	432.0	433.0	436.3	438.5	434.0	433.7
11	Downstream of a footbridge	443.0	437.9	438.7	441.6	443.5	431.7	432.7
12	Downstream of Putnam St	446.0	442.2	443.0	446.2	448.3	442.0	444.6
13	Upstream of railroad #3	447.0	442.1	443.2	447.3	450.0	444.2	445.3
14	Upstream of railroad #3	450.0	443.4	444.5	448.8	451.7	446.0	446.7
15	Downstream of railroad #4	450.0	444.3	445.4	449.4	452.1	447.7	447.4
16	Upstream of railroad #4	453.0	447.6	448.5	451.9	454.2	448.7	450.3
17	Upstream of railroad #4	455.0	448.3	449.2	452.5	454.7	450.7	450.9
18	Downstream of Rollstone St	459.5	451.9	453.5	457.3	458.9	453.7	456.4
19	Downstream of Rollstone St	459.0	452.7	454.3	457.9	459.5	452.5	455.7
20	Upstream of Rollstone St	461.0	454.1	455.0	458.5	460.8	457.0	456.8
21	Downstream of Circle St	460.0	454.7	455.6	458.9	461.1	457.7	457.2
22	Upstream of Circle St	465.0	457.7	458.8	462.6	465.2	459.5	460.8
23	Upstream of Circle St	462.0	458.5	459.5	463.2	465.6	460.0	461.5
24	Downstream of River St	467.5	463.2	463.9	466.7	468.6	465.7	466.6
25	Upstream of River St	470.5	464.2	465.0	468.1	470.1	465.0	465.4
26	Upstream of River St	475.0	468.6	469.3	471.8	473.4	471.5	472.4
27	Upstream of River St	475.5	470.3	471.0	473.7	475.5	470.5	470.6
28	Downstream of Sheldon St	478.0	470.9	471.6	474.2	476.0	472.5	473.0
29	Downstream of Sheldon St	478.0	472.0	472.6	475.0	476.7	475.0	473.8
30	Upstream of Sheldon St	480.0	474.1	474.9	477.9	479.9	479.5	476.6
31	Downstream of River St	485.0	477.4	478.1	480.6	482.3	480.5	479.5
32	Upstream of River St	488.0	483.2	483.9	486.7	488.5	483.2	485.4
33	Upstream of Kimball St	495.5	484.5	485.3	488.2	490.2	489.2	486.8
34	Downstream of Daniels St	496.0	490.1	490.8	493.5	495.3	491.5	492.2
35	Upstream of Daniels St	498.0	490.9	491.6	494.1	495.8	492.2	492.9
36	Downstream of railroad #6	498.5	492.3	493.0	495.8	497.6	496.2	497.5
37	Upstream of railroad #6	499.5	492.6	494.7	499.5	501.6	494.0	494.4
38	Downstream of Oak Hill Rd	500.0	496.2	497.1	500.3	502.4	497.5	498.7
39	Upstream of Oak Hill Rd	500.0	494.8	497.2	502.8	505.2	498.2	500.5
40	Upstream of Oak Hill Rd	504.5	497.6	498.6	502.3	504.8	501.5	500.5
41	Upstream of Oak Hill Rd	510.0	500.3	501.4	505.4	508.1	503.0	503.4

Low Bank ID	Approximate Location	Estimated 100-yr Overtopping Depth (ft.) by Scenario					
		USGS Baseline	USGS Future	Effective (1991) FEMA Baseline	Effective (1991) FEMA Future	Draft FEMA Baseline	Draft FEMA Future
1	Upstream of Electric Station Dam	-7.8	-7.3	-5.1	-3.6	-9.5	-6.2
2	Upstream of Sawyers Pwy	-7.6	-6.7	-3.5	-1.3	-7.0	-5.1
3	Upstream of railroad #1	-6.0	-3.8	*1.1*	*3.2*	-4.0	-1.0
4	Downstream of Water St	-7.5	-5.5	-0.8	*1.2*	-4.5	-3.6
5	Downstream of Water St	-8.1	-6.0	-1.3	*0.7*	-5.3	-3.3
6	Upstream of Water St	-6.5	-5.5	-1.7	*0.8*	-4.8	-2.7
7	Downstream of Laurel St	-5.4	-4.5	-1.1	*1.2*	-3.0	-2.8
8	Upstream of Laurel St	-4.6	-3.7	-0.1	*2.3*	-4.3	-2.8
9	Upstream of railroad #2	-3.5	-2.5	*0.9*	*3.2*	-8.0	-8.4
10	Upstream of Commercial St	-11.0	-10.0	-6.7	-4.5	-0.5	-0.8
11	Downstream of a footbridge	-5.1	-4.3	-1.4	*0.5*	-2.8	-1.8
12	Downstream of Putnam St	-3.8	-3.0	*0.2*	*2.3*	-4.0	-1.4
13	Upstream of railroad #3	-4.9	-3.8	*0.3*	*3.0*	-2.8	-1.7
14	Upstream of railroad #3	-6.6	-5.5	-1.2	*1.7*	-4.0	-3.3
15	Downstream of railroad #4	-5.7	-4.6	-0.6	*2.1*	-2.3	-2.6
16	Upstream of railroad #4	-5.4	-4.5	-1.1	*1.2*	-4.3	-2.7
17	Upstream of railroad #4	-6.7	-5.8	-2.5	-0.3	-4.3	-4.1
18	Downstream of Rollstone St	-7.6	-6.0	-2.2	-0.6	-5.3	-2.6
19	Downstream of Rollstone St	-6.3	-4.7	-1.1	*0.5*	-7.0	-3.8
20	Upstream of Rollstone St	-6.9	-6.0	-2.5	-0.2	-4.0	-4.2
21	Downstream of Circle St	-5.3	-4.4	-1.1	*1.1*	-2.3	-2.8
22	Upstream of Circle St	-7.3	-6.2	-2.4	*0.2*	-5.5	-4.2
23	Upstream of Circle St	-3.5	-2.5	*1.2*	*3.6*	-2.0	-0.5
24	Downstream of River St	-4.3	-3.6	-0.8	*1.1*	-4.8	-3.9
25	Upstream of River St	-6.3	-5.5	-2.4	-0.4	-2.5	-2.1
26	Upstream of River St	-6.4	-5.7	-3.2	-1.6	-4.0	-3.1
27	Upstream of River St	-5.2	-4.5	-1.8	*0.0*	-4.5	-4.4
28	Downstream of Sheldon St	-7.1	-6.4	-3.8	-2.0	-5.5	-5.0
29	Downstream of Sheldon St	-6.0	-5.4	-3.0	-1.3	-3.0	-4.2
30	Upstream of Sheldon St	-5.9	-5.1	-2.1	-0.1	-0.5	-3.4
31	Downstream of River St	-7.6	-6.9	-4.4	-2.7	-4.5	-5.5
32	Upstream of River St	-4.8	-4.1	-1.3	*0.5*	-4.8	-2.6
33	Upstream of Kimball St	-11.0	-10.2	-7.3	-5.3	-6.3	-8.7
34	Downstream of Daniels St	-5.9	-5.2	-2.5	-0.7	-4.5	-3.8
35	Upstream of Daniels St	-7.1	-6.4	-3.9	-2.2	-5.8	-5.1
36	Downstream of railroad #6	-6.2	-5.5	-2.7	-0.9	-3.3	-2.0
37	Upstream of railroad #6	-6.9	-4.8	*0.0*	*2.1*	-4.5	-4.1
38	Downstream of Oak Hill Rd	-3.8	-2.9	*0.3*	*2.4*	-2.5	-1.3
39	Upstream of Oak Hill Rd	-5.2	-2.8	*2.8*	*5.2*	-1.8	*0.5*
40	Upstream of Oak Hill Rd	-6.9	-5.9	-2.2	*0.3*	-3.0	-4.0
41	Upstream of Oak Hill Rd	-9.7	-8.6	-4.6	-1.9	-7.0	-6.6

Note: red italicized values indicate a location where the North Nashua River is expected to overtop the FDR System.

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

- Existing 9,000-cfs Water Surface (WS)
- 9,000-cfs WS with New Recommendations
- 9,000-cfs WS Goal of Previous Rehabilitation
- Channel Minimum
- Approximate Low Bank

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.

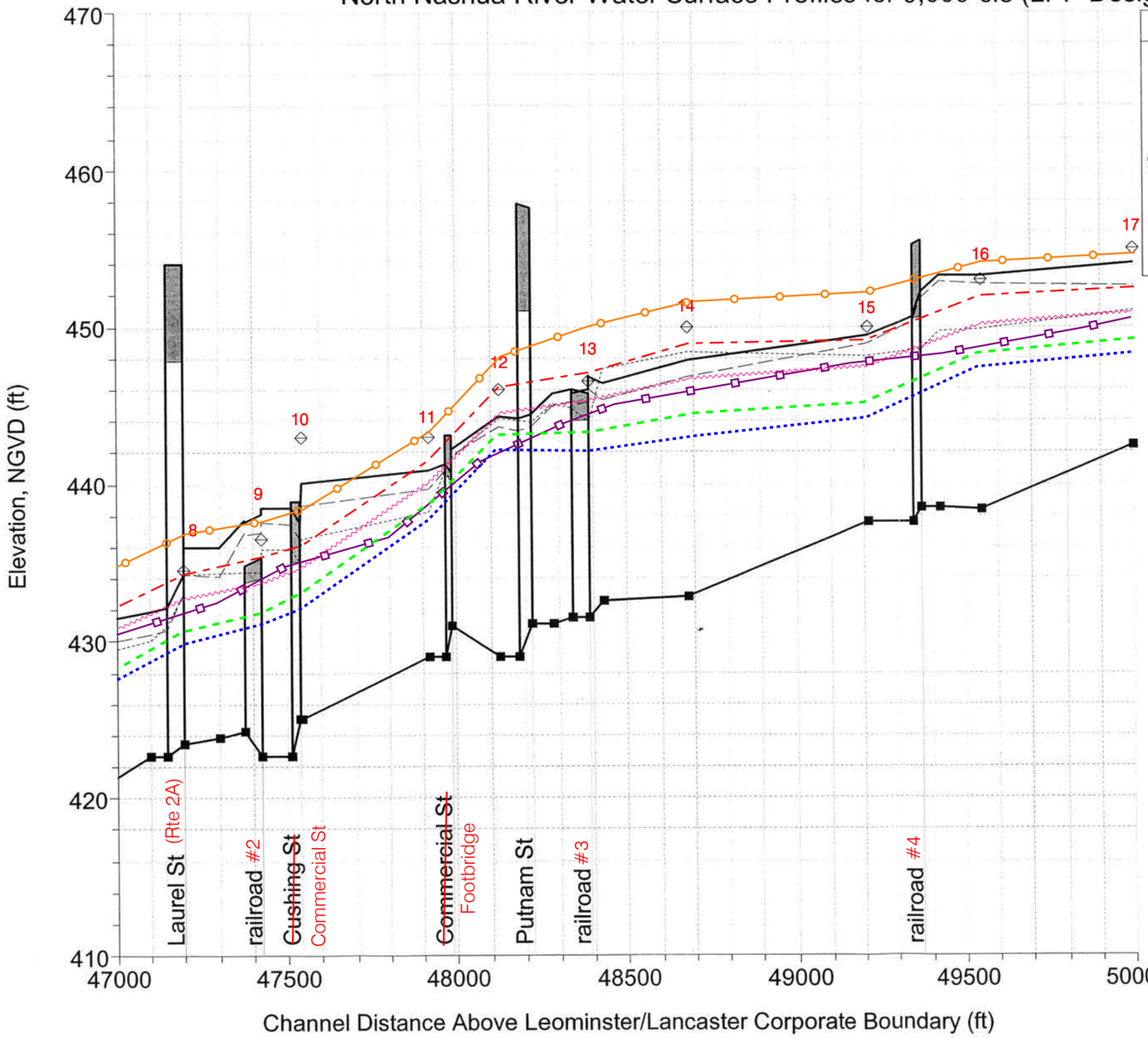
- Future Climate Equivalent of the FEMA 100-yr Flood WS
- Future Climate Equivalent of the 100-yr Flood WS
- Future Climate Equivalent of the New Draft FEMA 100-yr Flood WS
- FEMA 100-yr Flood WS
- 100-yr Flood WS
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 1

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

- Existing 9,000-cfs Water Surface (WS)
- 9,000-cfs WS with New Recommendations
- 9,000-cfs WS Goal of Previous Rehabilitation
- Channel Minimum
- Approximate Low Bank

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.

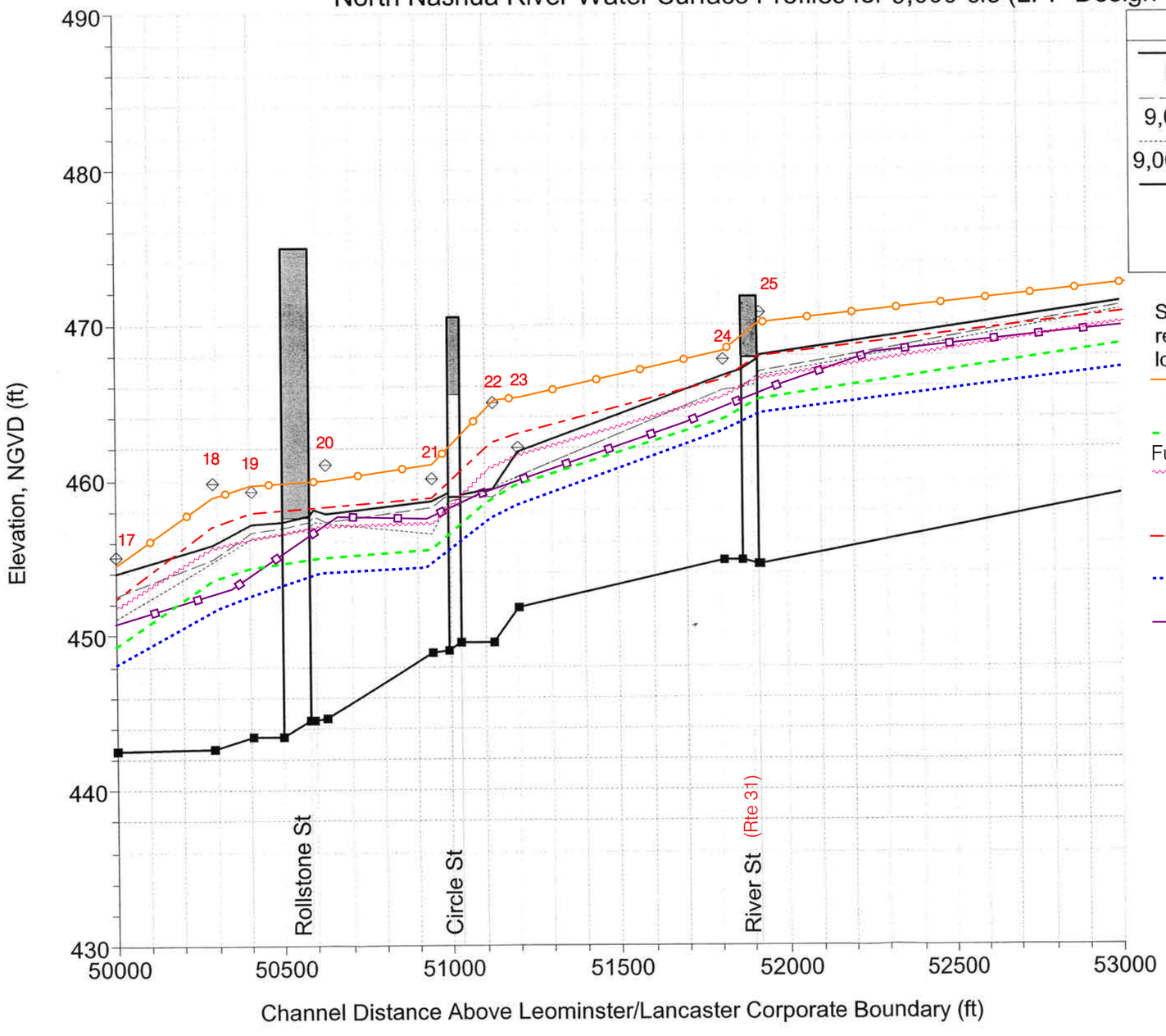
- Future Climate Equivalent of the FEMA 100-yr Flood WS
- Future Climate Equivalent of the 100-yr Flood WS
- Future Climate Equivalent of the New Draft FEMA 100-yr Flood WS
- FEMA 100-yr Flood WS
- 100-yr Flood WS
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 2

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

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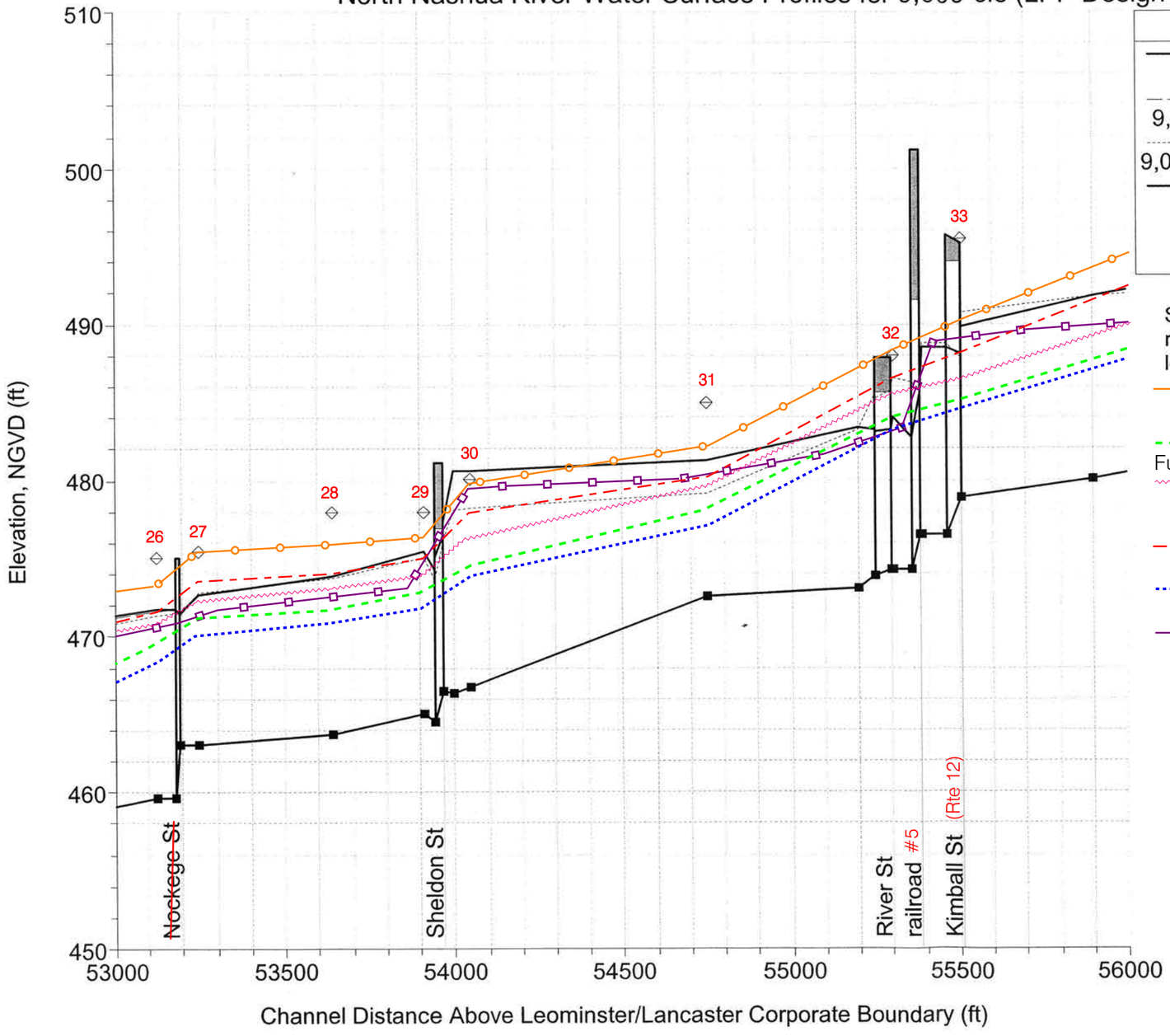
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 3

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

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- Channel Minimum
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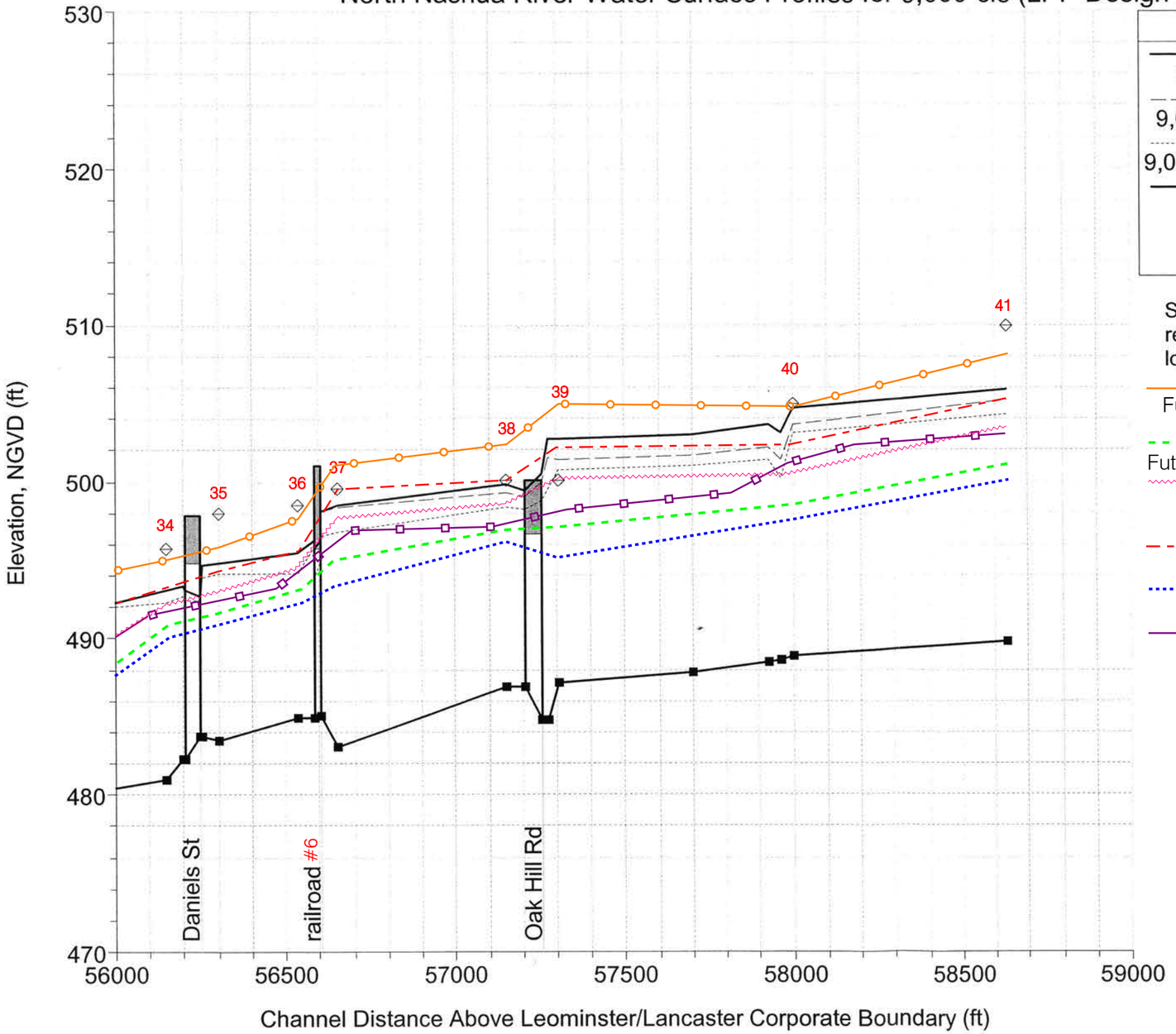
- FEMA 100-yr Flood WS
- 100-yr Flood WS
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 4

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

Existing 9,000-cfs Water Surface (WS)

9,000-cfs WS with New Recommendations

9,000-cfs WS Goal of Previous Rehabilitation

Channel Minimum

Approximate Low Bank

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.

Future Climate Equivalent of the FEMA 100-yr Flood WS

Future Climate Equivalent of the 100-yr Flood WS

Future Climate Equivalent of the New Draft FEMA 100-yr Flood WS

FEMA 100-yr Flood WS

100-yr Flood WS

New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 5

55 Walkers Brook Drive, Suite 100, Reading, MA 01867
Tel: 978.532.1900

MEMORANDUM

TO: Nick Erickson, PE (City of Fitchburg)

FROM: Andrew Walker, PH, CFM and Deanna Lambert, EIT (Weston & Sampson, Inc.)

DATE: April 29, 2020

SUBJECT: Flooding Impacts Memorandum

Weston & Sampson was hired by the City of Fitchburg to conduct a vulnerability assessment of the North Nashua River Flood Damage Reduction (FDR) System in Fitchburg, MA. The FDR System is an approximately five-mile stretch of flood protection along the North Nashua River. The City of Fitchburg has been provided $65,000 through a Municipal Vulnerability Preparedness (MVP) Planning Grant to fund this effort. The goal of the vulnerability assessment is to assess the condition and evaluate potential future flooding risks of the existing FDR System. This memo documents Weston & Sampson's efforts to identify the 100-year flooding extents in the North Nashua River under baseline and late 21st century future climate scenarios.

As described in the March 2020 Flood Risk memorandum, 100-year flood levels in the North Nashua River, under baseline and future climate scenarios, were estimated from three different datasets. The three datasets included:

1. Streamflow data recorded at the United States Geological Survey (USGS) gage on the North Nashua River (01094400);
2. The currently effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS), developed in 1991; and
3. The new Draft FEMA FIS.

Design flows for the USGS, 1991 FEMA, and Draft FEMA 100-year design floods under a baseline climate scenario were 71.9, 177.5, and 103.9 cubic feet per second per square mile (cfsm), respectively, Late 21st century design flows were assumed to be approximately 31.4% greater as documented in the March 2020 Flood Risk memo. Therefore, the USGS, 1991 FEMA, and Draft FEMA 100-year design flows under a future climate scenario were 94.5, 233.2, and 136.5 cfsm, respectively.

Methodology

To identify vulnerable areas and critical infrastructure within the City of Fitchburg, Weston & Sampson delineated the anticipated extents of flooding associated with each of the three baseline and three future climate scenarios. The river flood level profiles developed in support of the March 2020 Flood Risk memo, which are attached to this memo, were converted into a GIS database. The database consisted of 41 points locations along the North Nashua River centerline, each point corresponding to the approximate location of the 41 low bank elevations shown in the river profiles. Weston & Sampson then developed hydraulically appropriate cross-sections at each of those 41 locations. The cross-sections extended from one side of the North Nashua River valley to the other, fully encompassing the river channel, both sides of the floodplain, and the low-lying areas of Fitchburg. Each of the 41 cross-sections was assigned the low bank elevation data and six estimated 100-year flood levels associated with its corresponding location along the river profiles.

A series of GIS tools were then used to develop six gridded datasets, known as rasters, to represent each of the six flood scenarios. Those gridded datasets were compared to the latest LiDAR dataset, representative of bare earth ground elevations within Fitchburg, producing a set of six rasters indicative to the anticipated depth of flooding in the floodplain and over the normal water level in the channel itself. These flood depth rasters were reclassified so that all areas with positive flood depths, indicating wet areas, were assigned one value, and all areas with negative flood depths, indicative of dry land, were assigned a different value. These rasters were then converted to six GIS polygon shapefiles. Dry land polygons were removed, leaving only a delineation of areas expected to be inundated under each of the six hydrologic scenarios. These delineations were then refined manually, including small edits such as:

- Removing areas of flooding that are isolated from the river channel;
- Removing areas of flooding that connect to the river channel at only a single point and that are less than 10 square feet;
- Removing bridge crossings that are shown in the river profiles not to be overtopped;
- Smoothing out unrealistically sharp bends in the inundation extents caused by isolated discrepancies in the LiDAR data that were created when its creators removed rooftops in an effort to create a “bare earth” surface; and
- Making small edits to ensure that hydrologic scenarios with higher flood levels have inundation extents greater than or equal to scenarios with lower flood levels.

These manual edits were relatively minor and generally made with a conservative mindset to ensure that the mapped inundation extents do not underestimate flooding impacts. Ultimately, the final inundation extents were incorporated into two flood inundation maps, one for the baseline climate scenario and one for the late 21st century future climate scenario. These maps are attached to the end of this memo.

Results

Based on the inundation extents depicted in the attached inundation maps, Weston & Sampson evaluated the potential impacts of flooding under both climate scenarios and under the three hydrologic conditions. As discussed briefly in the March 2020 Flood Risk memo, the 100-year flow identified in the 1991 FEMA FIS appears to be unusually high, inconsistent with streamflow data that the USGS has been collecting immediately downstream of the project area from 1973 to present. There is some evidence to suggest that those 1991 FEMA values are erroneously high due to a misidentified watershed area, although that is unclear. Regardless, FEMA is currently updating their FIS for the North Nashua River, and appears to have addressed the issue, as the 100-year flow identified in their current Draft FIS is much more consistent with estimates from USGS gage data. For the purposes of evaluating potential flooding impacts, we consider the hydrologic conditions developed from the Draft FEMA FIS and the USGS data to represent a reasonable range of potential impacts. Impacts associated with the 1991 FEMA FIS may have value as a sort of "worst-case" scenario. The following table summarizes the total inundation area and potential impacts for each of the six climate-hydrologic condition scenarios:

Climate Scenario	Hydrologic Condition	Inundation Area (Acres)	Number of Impacted Buildings
Baseline	USGS 100-year	40.8	22
	Draft FEMA 100-year	60.2	36
	1991 FEMA 100-year	114.9	67
Future (2070)	USGS 100-year	49.2	29
	Draft FEMA 100-year	78.8	44
	1991 FEMA 100-year	151.6	87

Under a baseline climate scenario, USGS 100-year hydrologic conditions are expected to flood approximately 40.8 acres within the downtown Fitchburg study area. Those inundation extents intersect 22 buildings as determined from the Building Structures database available through MassGIS, which was most recently updated in 2016. Impacts to key infrastructure include the MBTA Railroad crossing near Putnam St. and the North Central Charter Essential School. Under a baseline climate scenario, the Draft FEMA FIS 100-year hydrologic conditions are expected to produce generally similar impacts to its USGS counterpart, flooding 60.2 acres and parts of 36 buildings. In addition to the MBTA Railroad crossing near Putnam St. and the North Central Charter Essential School, the Fitchburg City Hall may also be flooded. The worst-case conditions represented by the 1991 FEMA FIS inundation extents are significantly worse than the other two hydrologic conditions, flooding 114.9 acres and portions of 67 buildings. Additional "worst-case" impacts to critical infrastructure include overtopping of the Putnam St., Water St. (MA Rte. 12), and Sawyer Passway crossings. River St. (MA Rte. 31/MA Rte. 12) may be overtopped adjacent to the river crossing. An additional crossing of the MBTA Railroad line may also be inundated near the Fitchburg Riverfront Park, and additional flooding may occur in the Crocker Field and Central Plaza areas as well.

Flooding impacts are expected to worsen only modestly under a late 21st century future climate scenario. UGSS 100-year hydrologic conditions would be expected to inundate 49.2 acres and portions of 29 buildings, representing 21% and 32% increases over baseline climate conditions. Draft FEMA FIS 100-

year hydrologic conditions would be expected to inundate 78.8 acres and portions of 44 buildings, representing increases of 31% and 22%, respectively. Despite this increased flooding, no additional impacts to road crossings or critical infrastructure in the floodplain is expected over a baseline climate scenario. The 1991 FEMA FIS hydrologic conditions, which represent a "worst case," are estimated to inundate 151.6 acres and 87 buildings, increases of 32% and 30%, respectively. The River St. (MA Rte. 31/MA Rte. 12) crossing is expected to overtop, in addition to the impacts associated with the corresponding baseline climate scenario.

Flood depths at the locations identified above were estimated by comparing the estimated river levels for each scenario against the lowest ground elevation near each location as determined from the latest LiDAR data available through MassGIS. Those flood depths are summarized in the table below for each of the climate-hydrologic condition scenarios. *Note that negative flood depth values indicate that no flooding is expected to occur at those locations.*

Location	Baseline Climate			Future Climate (2070)		
	USGS 100-yr	Draft FEMA 100-yr	1991 FEMA 100-yr	USGS 100-yr	Draft FEMA 100-yr	1991 FEMA 100-yr
Oak Hill St.	*-5.2*	*-1.8*	2.8	*-2.5*	0.5	5.2
North Central Charter Essential School	2.2	3.2	6.3	3.1	4.7	8.4
River St. (MA Rte. 31/MA Rte. 12)	*-4.8*	*-4.8*	0.5	*-4.1*	*-2.6*	2.0
Fitchburg City Hall	*-2.6*	0.0	3.3	*-1.5*	0.7	6.0
MBTA RR X-ing near Putnam St.	*-3.9*	*-1.8*	1.3	*-2.8*	*-0.7*	4.0
Putnam St.	*-0.8*	*-1.0*	3.2	0.0	3.5	5.3
MBTA RR X-ing near Fitchburg Riverfront Park	*-4.0*	*-1.0*	0.4	*-3.0*	*-1.3*	2.7
Water St. (MA Rte. 12)	*-4.4*	*-2.0*	0.6	*-3.5*	*-1.8*	2.2

Flooding impacts at those critical infrastructure and river crossings are also called out in the attached inundation maps. The color floods incorporated into those inundation maps indicate the 1991 FEMA 100-year scenario's "worst case" flood depths throughout the floodplain to give the reader an idea of potential flood depths throughout the floodplain.

Next Steps

Following the identification of flood prone portions of the North Nashua River FDR in the March 2020 Flood Risk memo and the potential impacts to road/rail crossings and critical infrastructure in this memo, Weston & Sampson has begun to develop an Emergency Action Plan (EAP) to use to guide the City's emergency response in case of a failure, breach, or overtopping of the FDR and a Preliminary Plan of Action to help prioritize the City's efforts to maintain, repair, and otherwise improve the effectiveness and integrity of the FDR. Specifically, our next steps include:

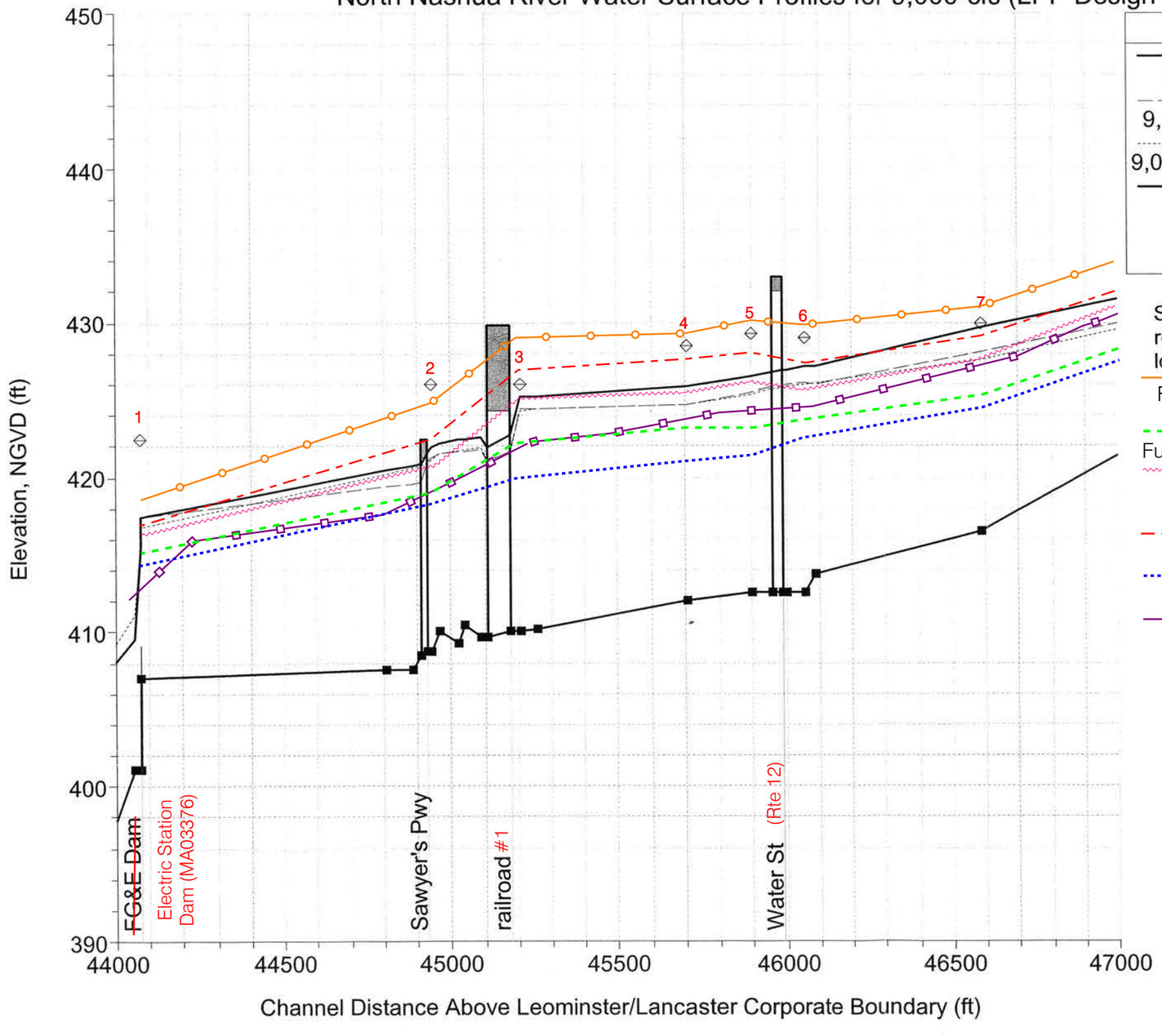
- Develop an Emergency Action Plan (EAP) for one levee, which can be used as a template for future EAPs;
- Develop a Preliminary Plan of Action, a report which summarizes a plan for updating and improving the flood control structures in Fitchburg along the North Nashua River;

- Develop, in concert with the Preliminary Plan of Action report, a summary table identifying critical projects and their associated potential ranges of costs for repairs, design, permitting, and construction.

Attachments:

River Flooding Profiles
Baseline Climate Inundation Maps
Future Climate (2070) Inundation Maps

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

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- Channel Minimum
- Approximate Low Bank

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.

- Future Climate Equivalent of the FEMA 100-yr Flood WS
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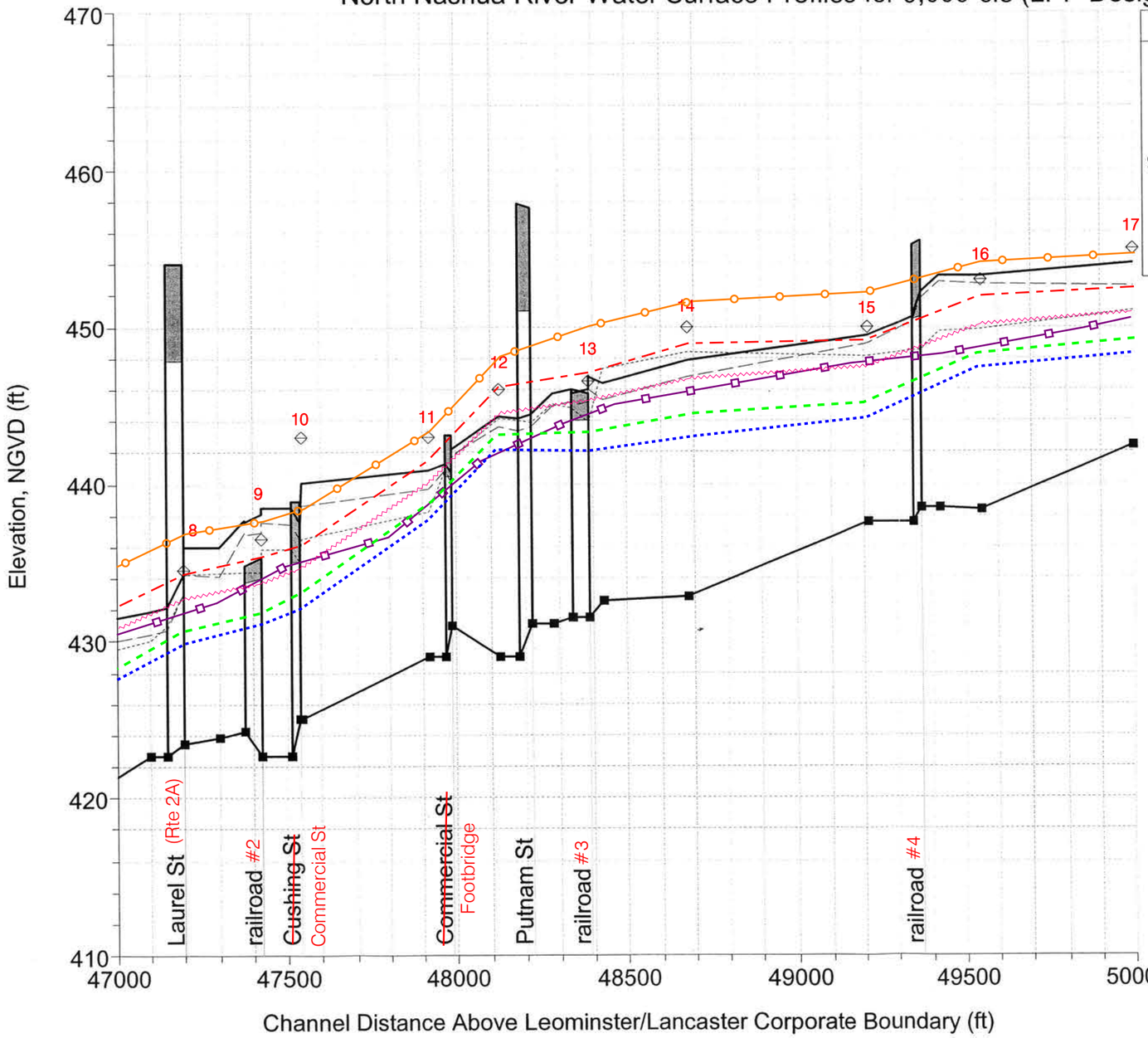
- 100-yr Flood WS
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 1

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



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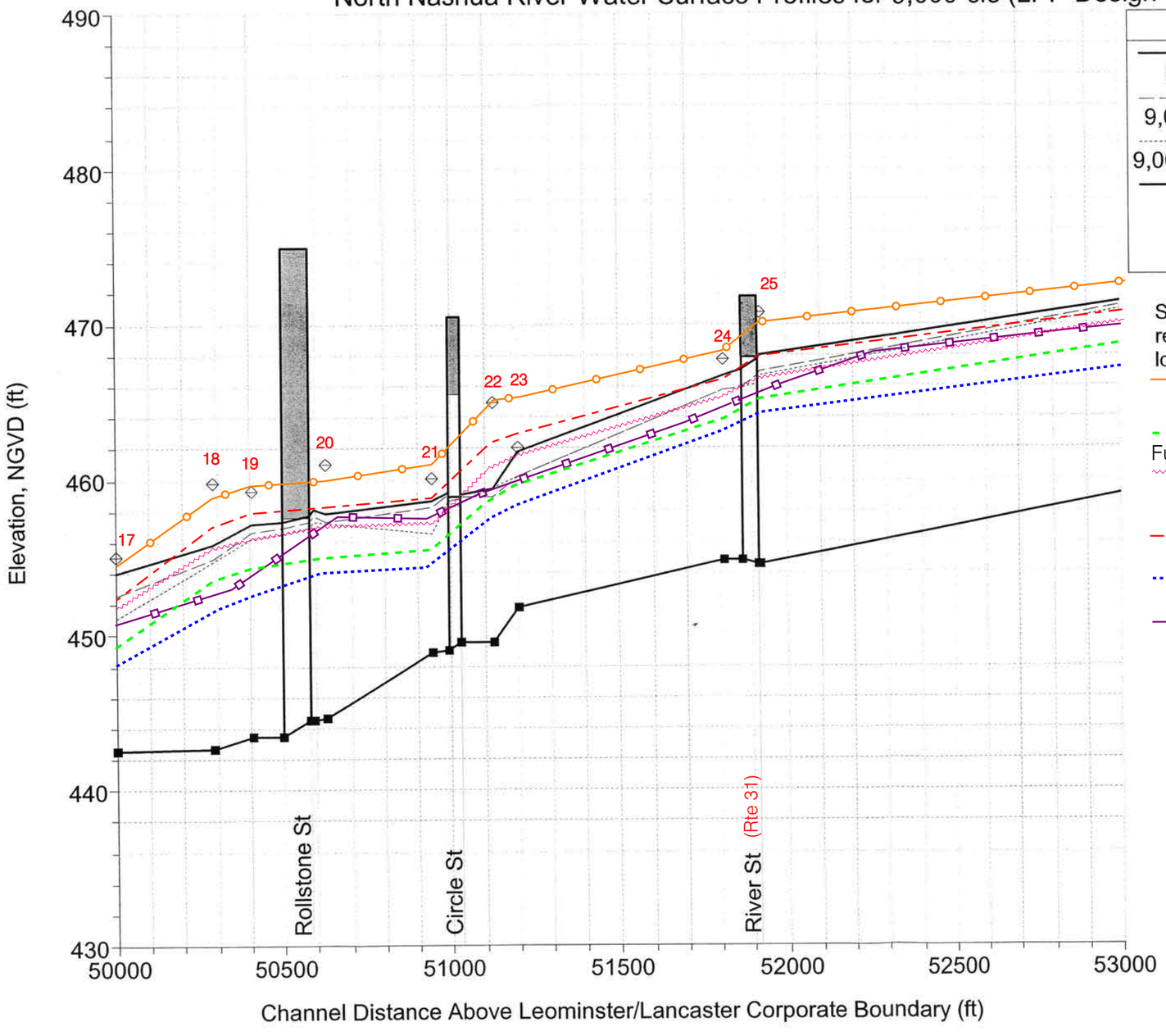
- 100-yr Flood WS
- New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 2

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



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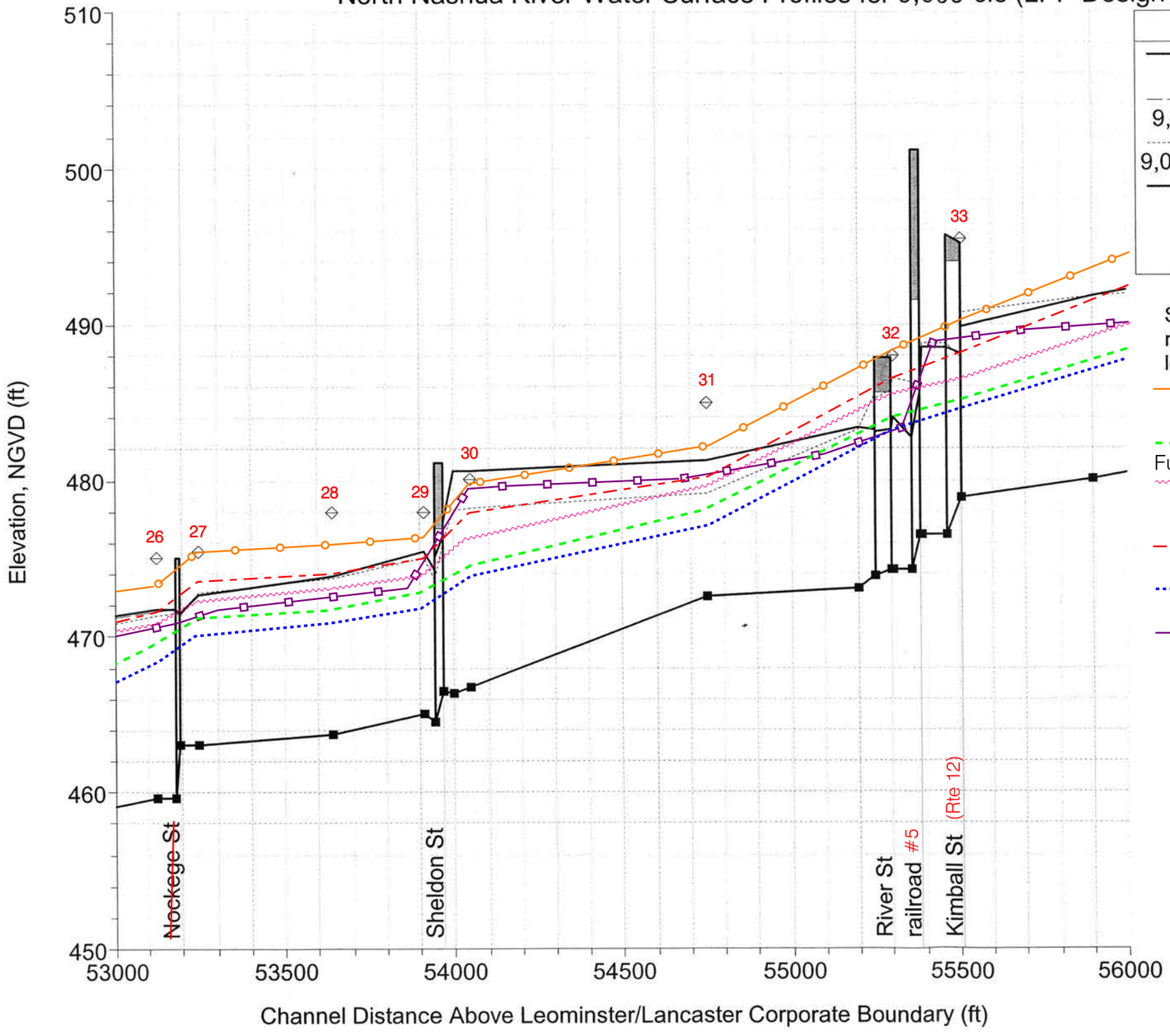
US Army Corps of Engineers

New England District

PROFILE 3

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



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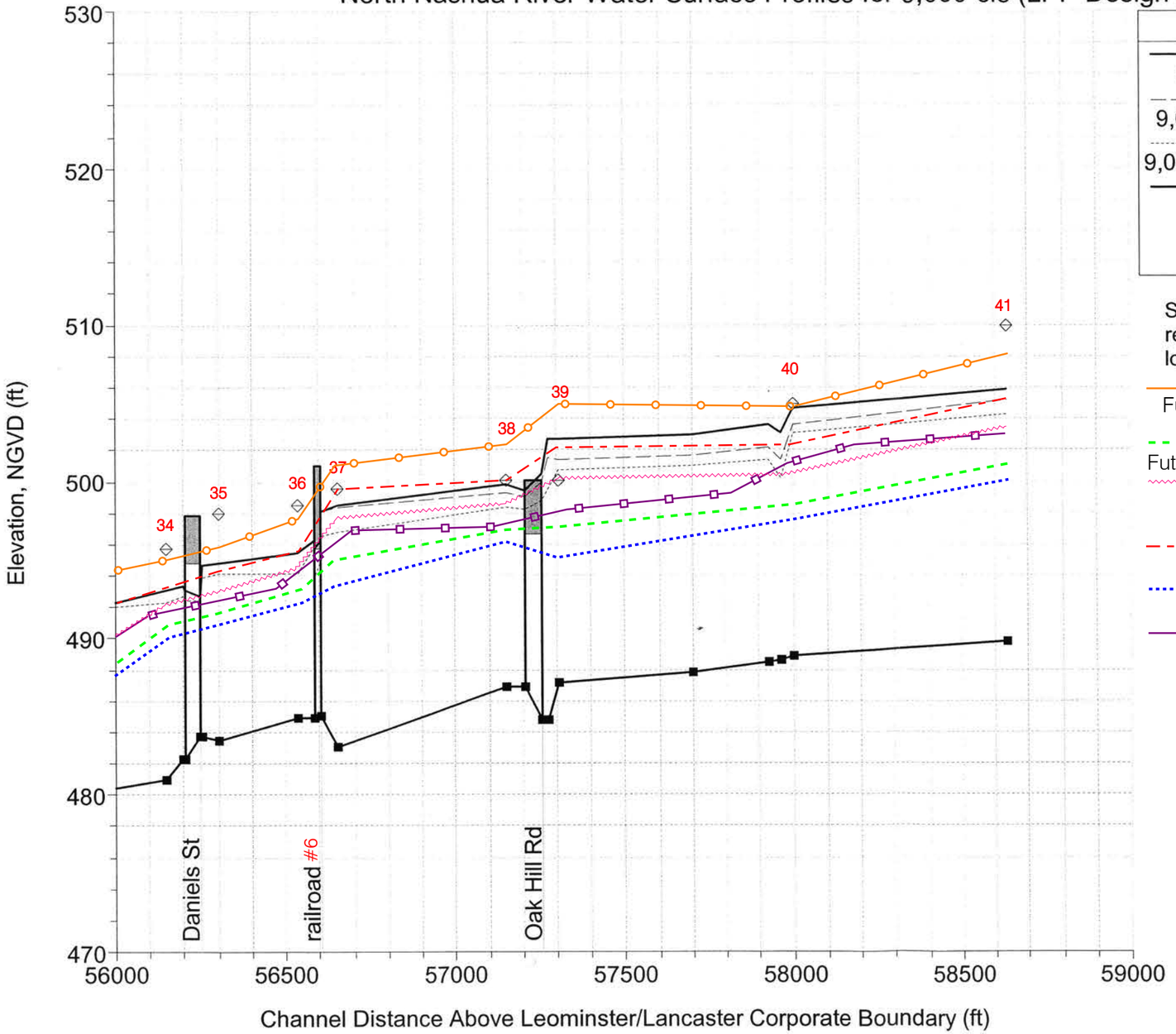
US Army Corps of Engineers

New England District

PROFILE 4

North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



Legend

Existing 9,000-cfs Water Surface (WS)

9,000-cfs WS with New Recommendations

9,000-cfs WS Goal of Previous Rehabilitation

Channel Minimum

Approximate Low Bank

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Future Climate Equivalent of the FEMA 100-yr Flood WS

Future Climate Equivalent of the 100-yr Flood WS

Future Climate Equivalent of the New Draft FEMA 100-yr Flood WS

FEMA 100-yr Flood WS

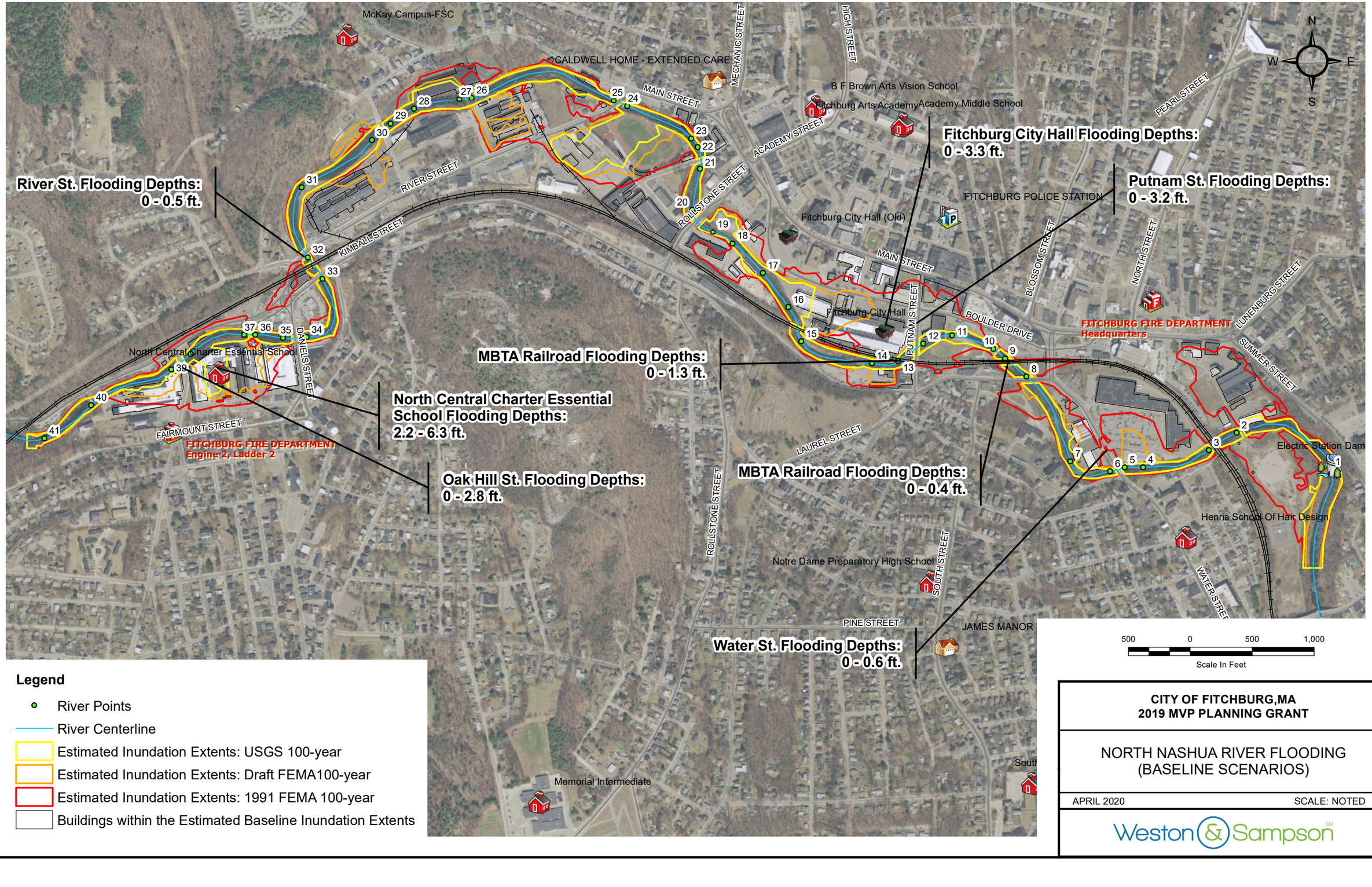
100-yr Flood WS

New Draft FEMA 100-yr Flood WS

US Army Corps of Engineers

New England District

PROFILE 5



Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS 100-year
- Estimated Inundation Extents: Draft FEMA100-year
- Estimated Inundation Extents: 1991 FEMA 100-year
- Buildings within the Estimated Baseline Inundation Extents

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(BASELINE SCENARIOS)

APRIL 2020 SCALE: NOTED

Weston & Sampson℠

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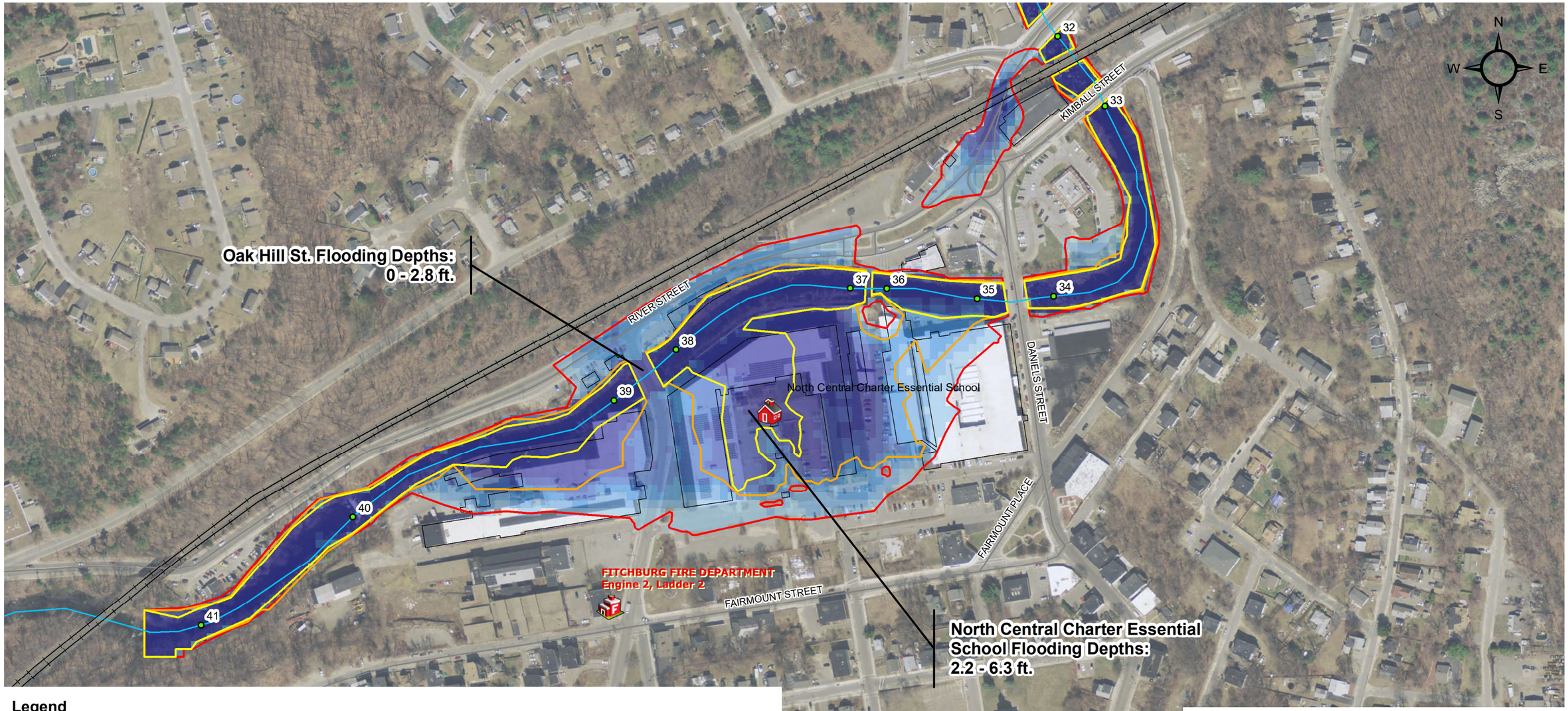

Legend

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- River Centerline
- Estimated Inundation Extents: USGS 100-year
- Estimated Inundation Extents: Draft FEMA100-year
- Estimated Inundation Extents: 1991 FEMA 100-year
- Buildings within the Estimated Baseline Inundation Extents

Flood Depth Under 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

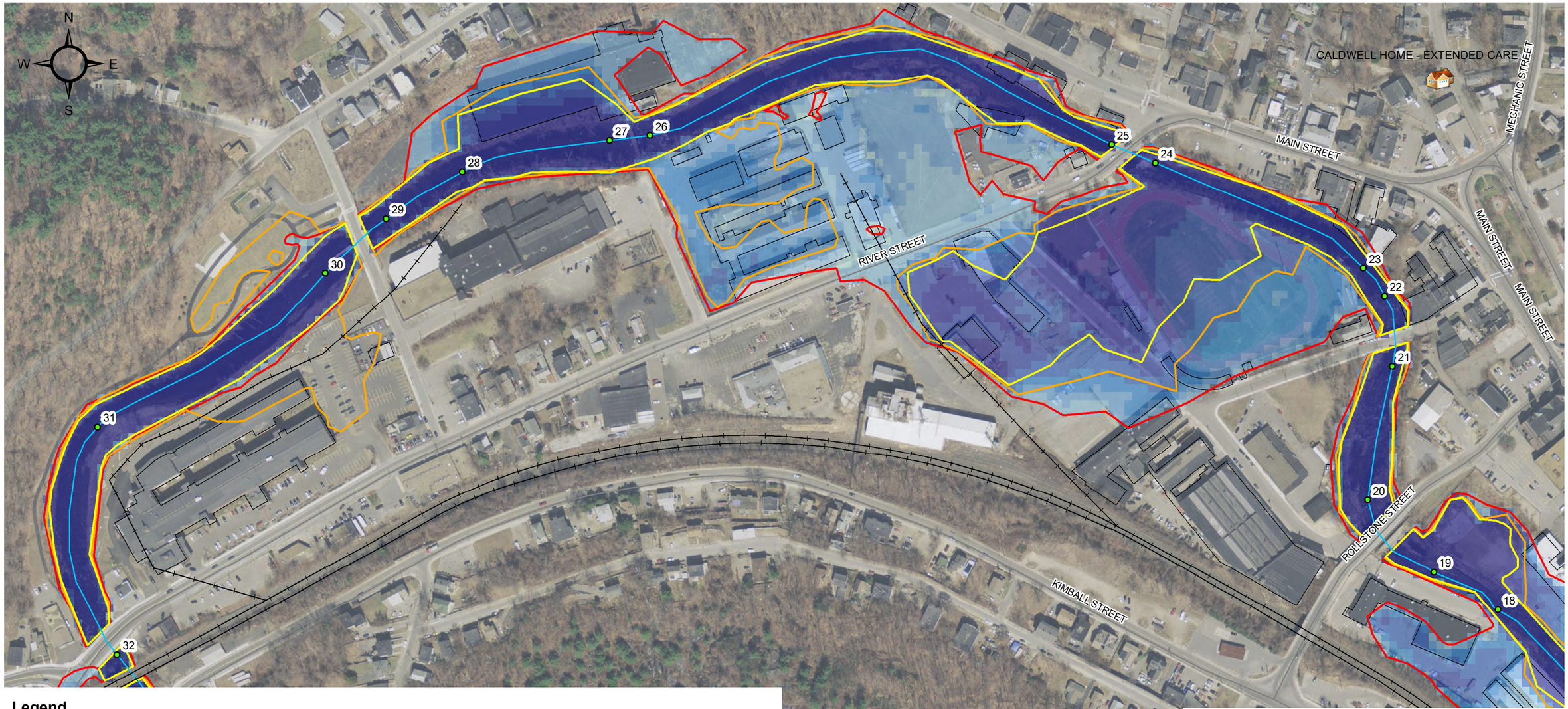
Scale In Feet

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(BASELINE SCENARIOS) - SHEET 1

APRIL 2020 SCALE: NOTED

Weston & Sampson℠



Legend

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- Estimated Inundation Extents: 1991 FEMA 100-year
- Buildings within the Estimated Baseline Inundation Extents

Flood Depth Under 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING (BASELINE SCENARIOS) - SHEET 2

APRIL 2020 SCALE: NOTED

Weston & Sampson

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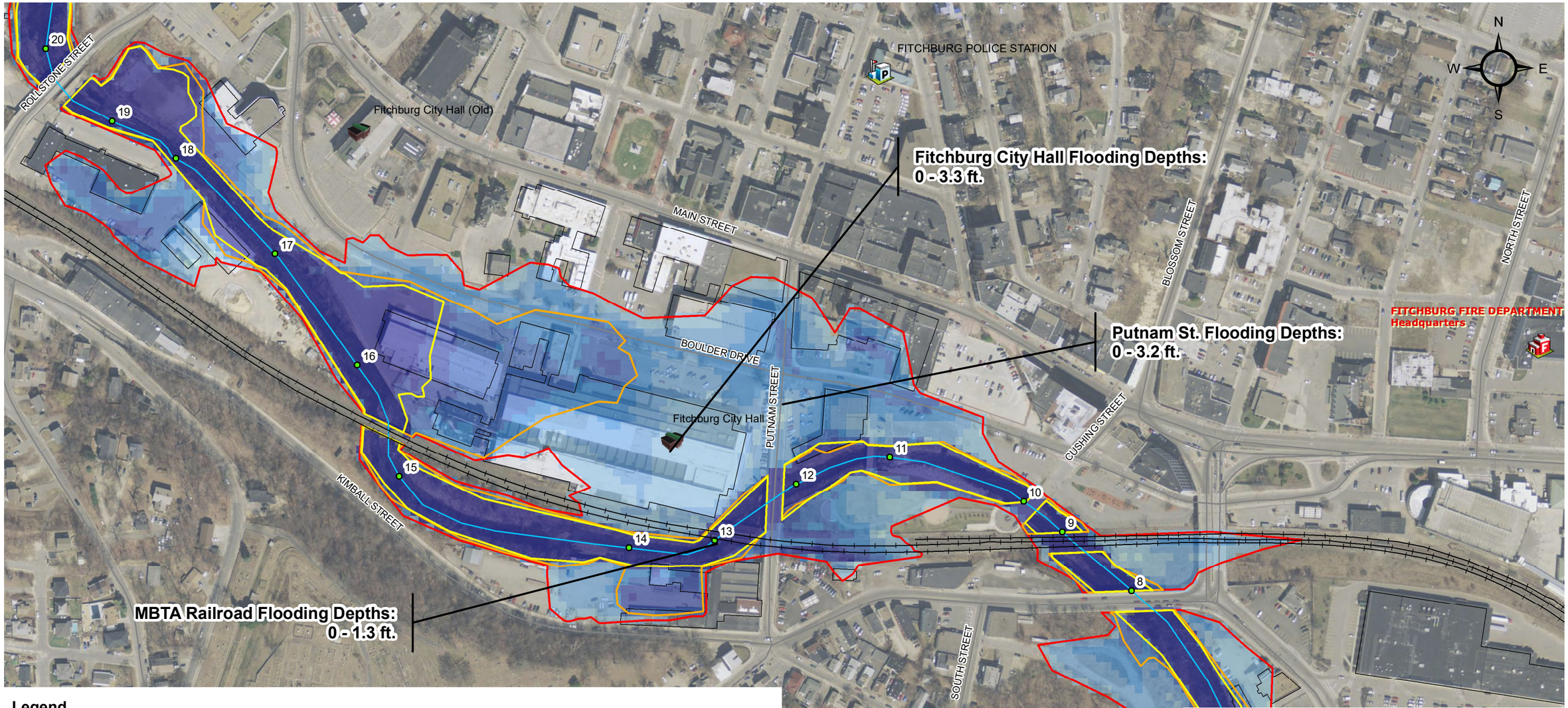

Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS 100-year
- Estimated Inundation Extents: Draft FEMA100-year
- Estimated Inundation Extents: 1991 FEMA 100-year
- Buildings within the Estimated Baseline Inundation Extents

Flood Depth Under 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(BASELINE SCENARIOS) - SHEET 3

APRIL 2020 SCALE: NOTED

Weston & Sampson

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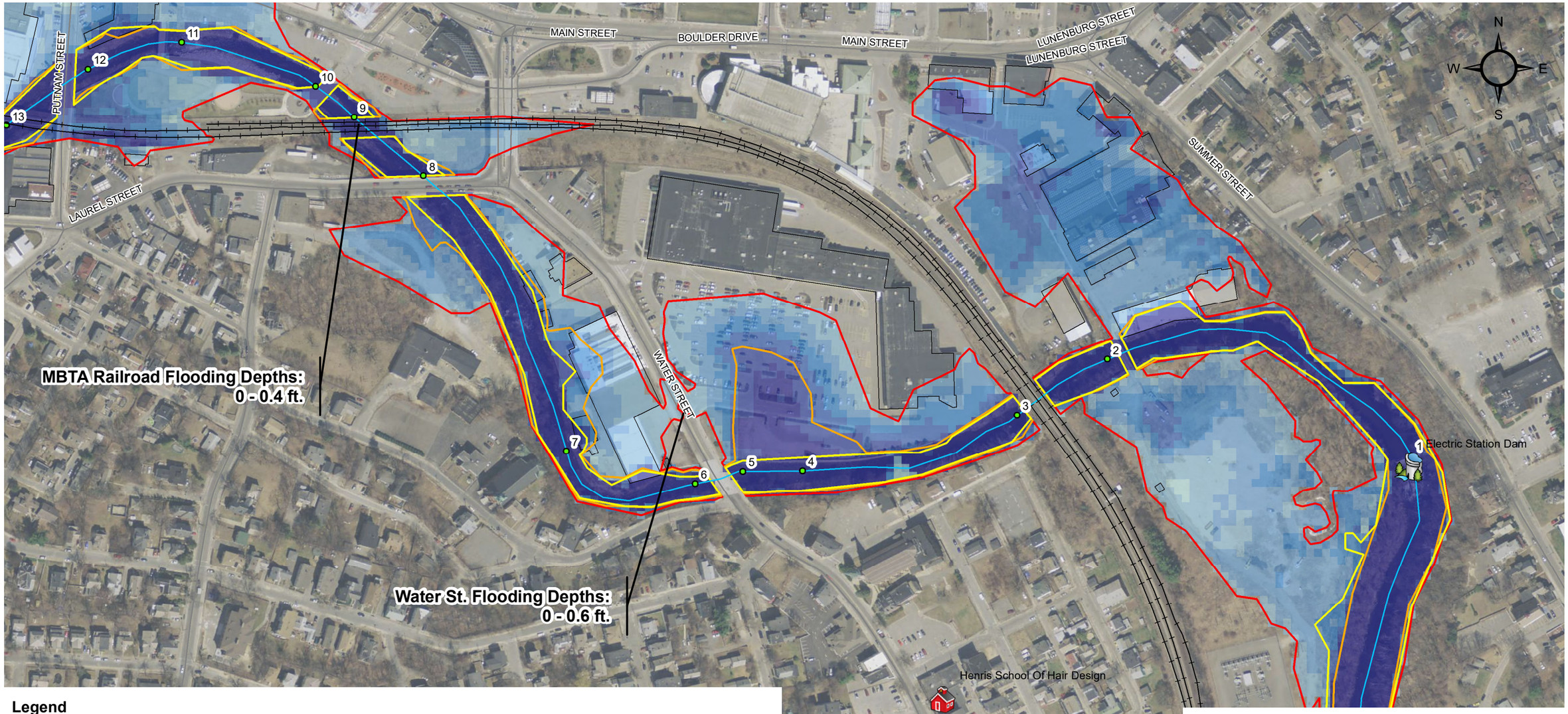

Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS 100-year
- Estimated Inundation Extents: Draft FEMA100-year
- Estimated Inundation Extents: 1991 FEMA 100-year
- Buildings within the Estimated Baseline Inundation Extents

Flood Depth Under 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(BASELINE SCENARIOS) - SHEET 4

APRIL 2020 SCALE: NOTED

Weston & Sampson SM

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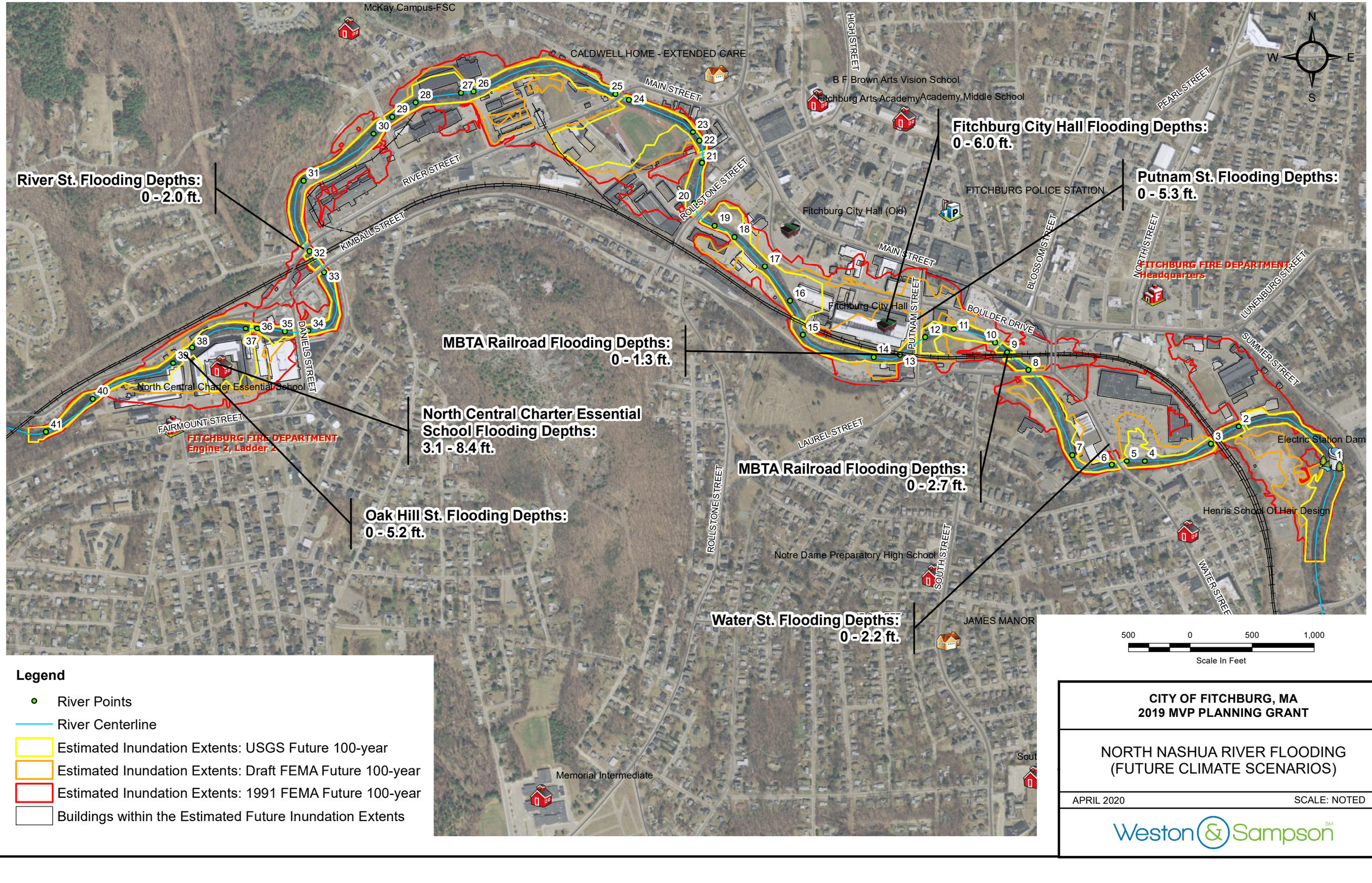


Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS Future 100-year
- Estimated Inundation Extents: Draft FEMA Future 100-year
- Estimated Inundation Extents: 1991 FEMA Future 100-year
- Buildings within the Estimated Future Inundation Extents

CITY OF FITCHBURG, MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING (FUTURE CLIMATE SCENARIOS)

APRIL 2020 SCALE: NOTED

Weston & Sampson

River St. Flooding Depths:
0 - 2.0 ft.

Oak Hill St. Flooding Depths:
0 - 5.2 ft.

North Central Charter Essential School Flooding Depths:
3.1 - 8.4 ft.

RIVER STREET
KIMBALL STREET
DANIELS STREET
FAIRMOUNT PLACE
FAIRMOUNT STREET
North Central Charter Essential School
FITCHBURG FIRE DEPARTMENT
Engine 2, Ladder 2

32 33 34 35 36 37 38 39 40 41

N W E S

Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS Future 100-year
- Estimated Inundation Extents: Draft FEMA Future 100-year
- Estimated Inundation Extents: 1991 FEMA Future 100-year
- Buildings within the Estimated Future Inundation Extents

Flood Depth Under Future 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400
Scale In Feet

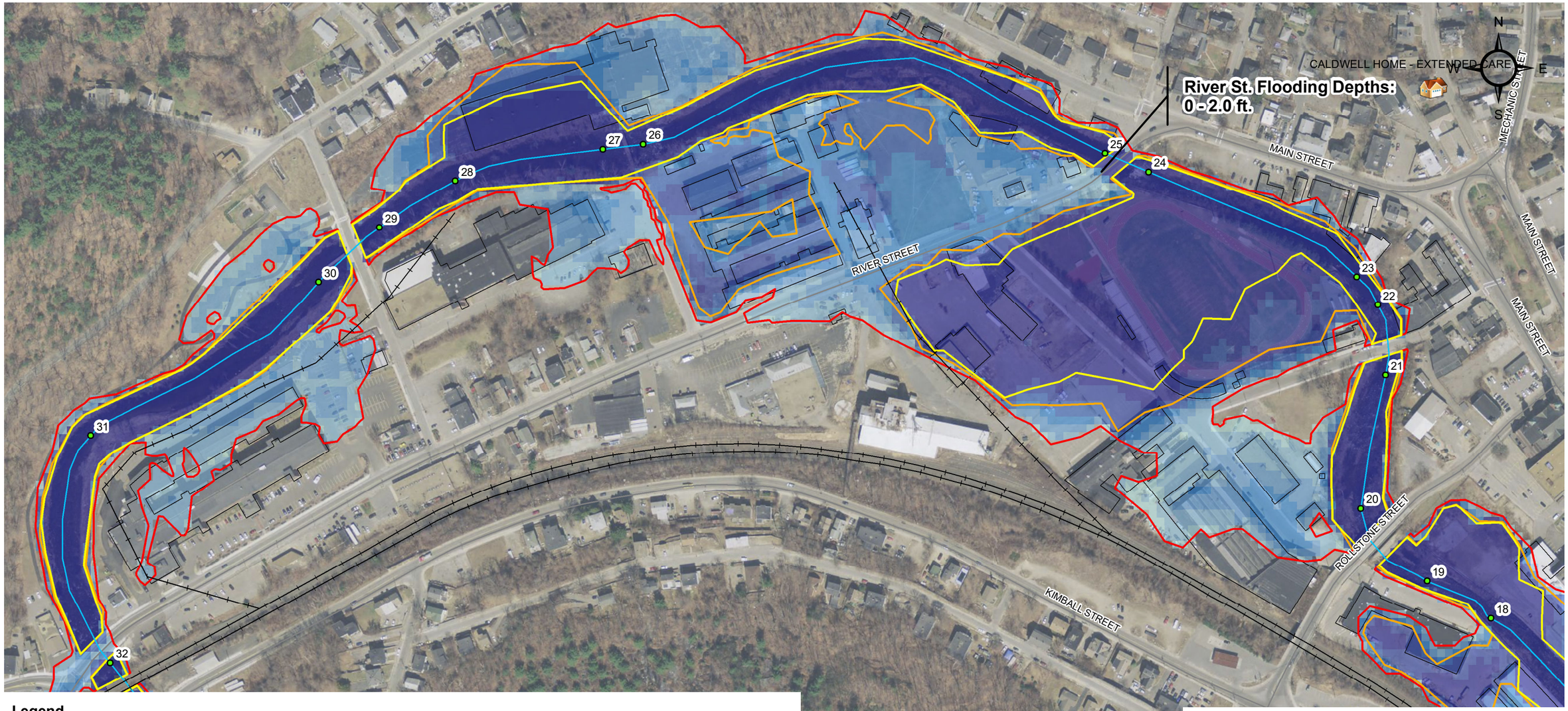
CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING (FUTURE CLIMATE SCENARIOS) - SHEET 1

APRIL 2020 SCALE: NOTED

Weston & Sampson

Path: C:\Users\lambertd\Documents\Projects\MA\Fitchburg\MVP\Mapfiles\Inundation Map - Future 100-Year Floods - Sheet 1.mxd **User:** LambertD **Saved:** 4/29/2020 10:33:10 AM **Opened:** 4/29/2020 10:34:06 AM



Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS Future 100-year
- Estimated Inundation Extents: Draft FEMA Future 100-year
- Estimated Inundation Extents: 1991 FEMA Future 100-year
- Buildings within the Estimated Future Inundation Extents

Flood Depth Under Future 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

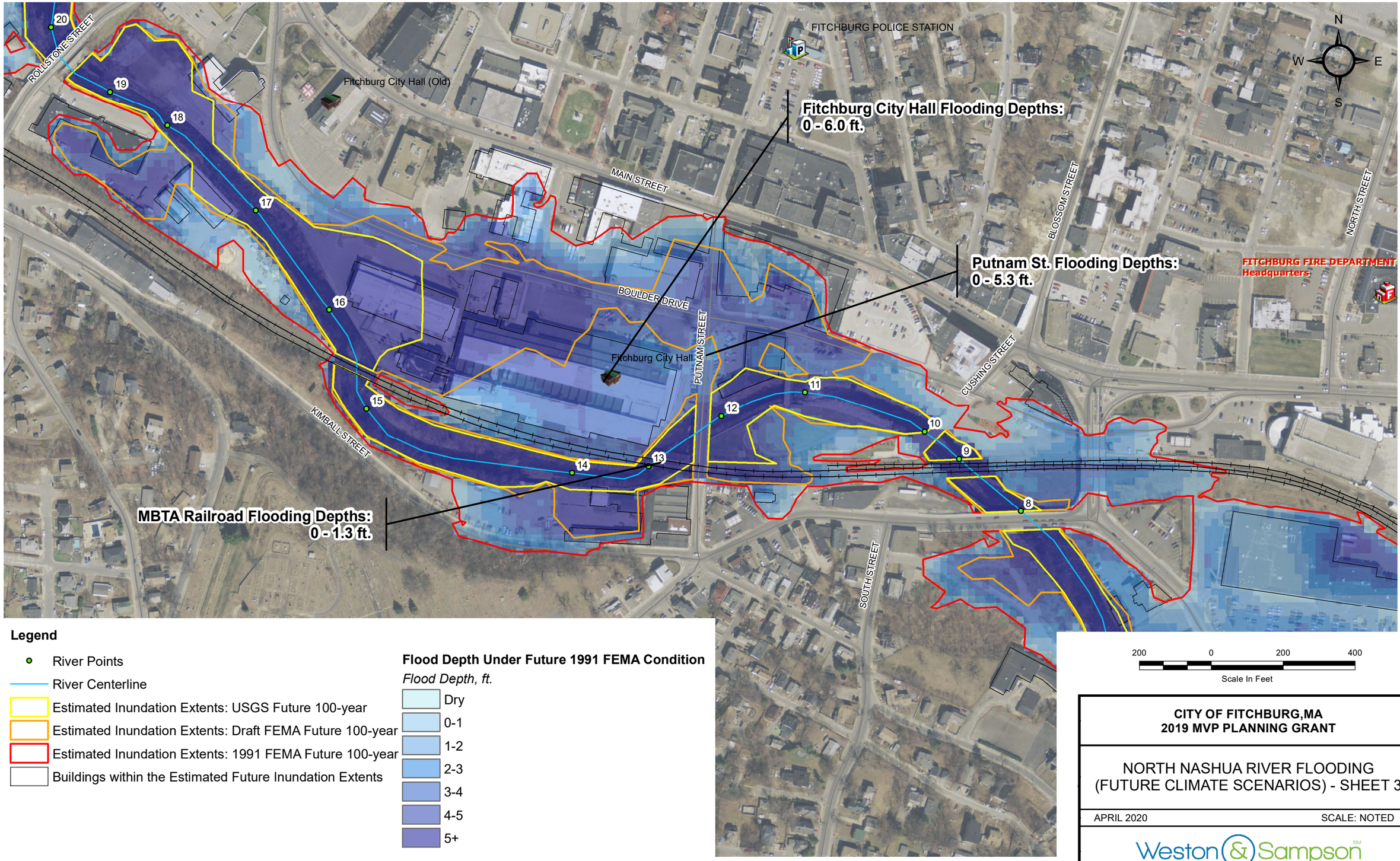
CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(FUTURE CLIMATE SCENARIOS) - SHEET 2

APRIL 2020 SCALE: NOTED

Weston & Sampson

Path: C:\Users\lambertd\Documents\Projects\MA\Fitchburg\MVP\Mapfiles\Inundation Map - Future 100-Year Floods - Sheet 2.mxd **User:** LambertD **Saved:** 4/29/2020 10:37:46 AM **Opened:** 4/29/2020 10:38:51 AM



Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS Future 100-year
- Estimated Inundation Extents: Draft FEMA Future 100-year
- Estimated Inundation Extents: 1991 FEMA Future 100-year
- Buildings within the Estimated Future Inundation Extents

Flood Depth Under Future 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

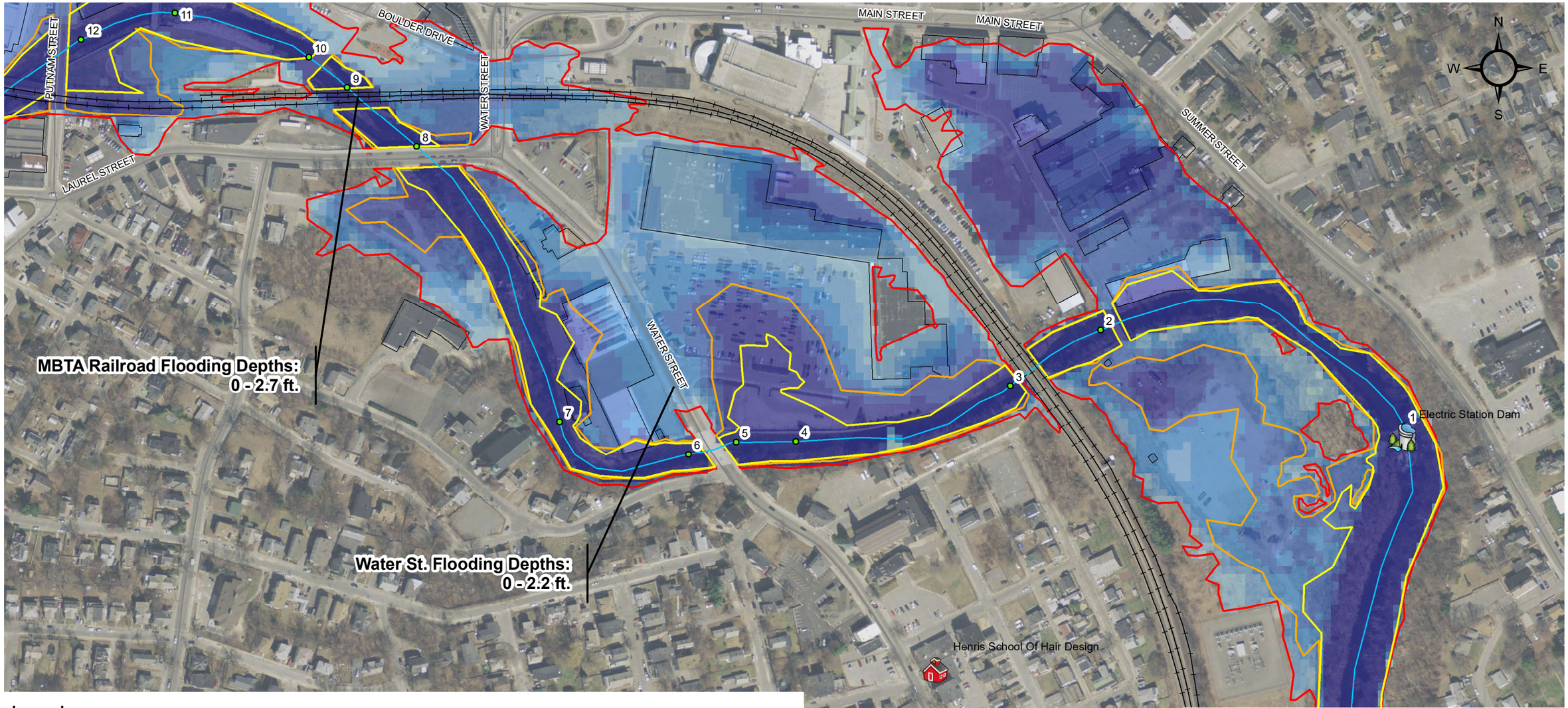
CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING
(FUTURE CLIMATE SCENARIOS) - SHEET 3

APRIL 2020 SCALE: NOTED

Weston & Sampson SM

Path: C:\Users\lambertd\Documents\Projects\MA\Fitchburg\MVP\Mapfiles\Inundation Map - Future 100-Year Floods - Sheet 3.mxd **User:** LambertD **Saved:** 4/29/2020 10:41:20 AM **Opened:** 4/29/2020 10:42:33 AM



Legend

- River Points
- River Centerline
- Estimated Inundation Extents: USGS Future 100-year
- Estimated Inundation Extents: Draft FEMA Future 100-year
- Estimated Inundation Extents: 1991 FEMA Future 100-year
- Buildings within the Estimated Future Inundation Extents

Flood Depth Under Future 1991 FEMA Condition

Flood Depth, ft.

- Dry
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5+

200 0 200 400

Scale In Feet

CITY OF FITCHBURG,MA
2019 MVP PLANNING GRANT

NORTH NASHUA RIVER FLOODING (FUTURE CLIMATE SCENARIOS) - SHEET 4

APRIL 2020 SCALE: NOTED

Weston & Sampson

Path: C:\Users\lambertd\Documents\Projects\MA\Fitchburg\MVP\Mapfiles\Inundation Map - Future 100-Year Floods - Sheet 4.mxd **User:** LambertD **Saved:** 4/29/2020 10:47:21 AM **Opened:** 4/30/2020 9:42:13 AM